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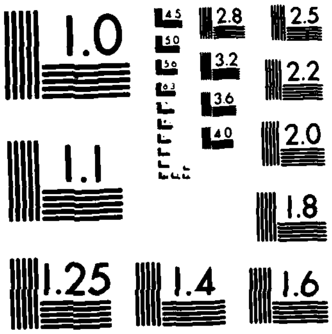

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DREDGING OPERATIONS TECHNICAL SUPPORT PROGRAM

TECHNICAL REPORT D-84-3

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

by

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September 1984

Final Report

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Material dredged from Ashtabula Harbor and River in 1975 and 1976 was placed at three Lake Erie disposal sites. The disposal operations were studied during the Dredged Material Research Program, 1973-1978. This report discusses animal, sediment, and water samples obtained from the three disposal sites and two nearby reference areas in 1979. Sediment characteristics, benthic animals, and mercury and cadmium levels were studied.

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20. ABSTRACT (Continued).

Disposal sites contained more gravel and sand than the reference sites which were predominantly silt (≈58 percent) and clay (≈33 percent). Disposal areas contained approximately 26 percent sand compared to 9 percent for the reference areas. It appears that some additional disposal of sand and gravel occurred at the disposal areas between 1976 and 1979.

A number of large (macrofauna) and small (meiofauna) benthic animals were found at both disposal and reference areas. In general, more macrofaunal animals and a greater variety of species were found at the reference areas. One reference area was found to contain more meiofaunal animals compared to the three disposal areas; however, the other reference site contained the lowest number of meiofauna of all the sites. Statistically significant differences were found only among the macrofauna and only for the mean number of taxa between the reference and disposal areas. The reference areas were higher.

Sediment analyses showed the reference or control areas contained higher levels of mercury (0.9 μg/g) compared to the disposal areas (0.7 μg/g). For cadmium, the opposite was true. There were higher cadmium levels at the disposal areas. The differences were not statistically significant. Very few tissue analyses were completed; results indicated animals at the reference areas contained higher levels of mercury and cadmium compared to disposal area animals.

Data obtained in 1979 are discussed in relation to the earlier studies conducted in 1975 and 1976.

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SUMMARY

Ashtabula Harbor, an important coal and ore transshipment center, is located on the southern shore of Lake Erie approximately 80 km east of Cleveland. Channel maintenance projects has been conducted since 1909, with the dredged material deposited in open water.

In 1975 and 1976, the U.S. Army Corps of Engineers' Dredged Material Research Program (DMRP) studied the short-term impact of dredged material disposal in Lake Erie. The present study, conducted in the summer of 1979, was designed as a follow-up to the DMRP program, as well as more recent disposal events. Long-term impacts of dredged material disposal on lake benthos and sediments were investigated. The first 20 cm of substrate was sampled and analyzed as two 10-cm horizons. Sediment grain-size distribution, macrofauna and meiofauna abundance and composition, and heavy metals content were studied.

The sampling area of the present study was chosen for its proximity to that of the previous investigation. Two control sites exhibited a natural continuum of grain sizes ranging from clayey silts to clean, fine-grained sands. Coarser grained material and shale were found in each of the three disposal sites.

The benthic macroinvertebrate community was found to be heterogeneous throughout the study area, with many taxa showing high spatial variability. Oligochaetes dominated the collections of both the control and disposal areas. Organism abundance and number of taxa were greater in the control than in the disposal areas. Such differences may have resulted as a function of substrate, since certain taxa exhibited a preference for specific sediment types. Nevertheless, no consistently significant differences were found between the control and disposal areas which would have indicated major long-term disposal effects.

The only significant differences were observed among the molluscs. Pelecypoda were significantly more abundant in control sites, while Gastropoda were significantly more abundant in disposal sites. However, since these conditions existed in the pre-disposal sampling in 1975, it is difficult to attribute these effects to the disposal of the dredged material.

The meiofaunal community showed greater numerical and spatial variability than that of the macrofauna. Total organism density and diversity were found to be greater in the disposal than in control areas for both strata. As noted also for the macrobenthos, however, meiofauna density and diversity in all study areas were markedly reduced in the lower versus the upper horizons. The Nematoda dominated all meiofauna collections.

Meiofaunal association with sediment appears to be bimodal, with greatest organism density occurring in the coarse-grained fraction and, secondarily, in fine-grained components. Although certain taxa were often more associated with a specific sediment type, no exclusive preference for a particular grain size was exhibited by any taxa. No disposal effect, other than providing a wider range of substrate habitat, was observed for the benthic meiofauna.

No statistically significant differences in the concentration of mercury or cadmium in interstitial water and sediments were observed between the disposal and control areas. Sediment and interstitial water concentrations of mercury and cadmium were similar to those reported in the DMRP study. Concentrations of mercury and cadmium in molluscs, and cadmium in oligochaetes, were higher in control than in disposal areas. Sample numbers, however, were inadequate for statistical comparison.

Although the disposal area sediments are not in predisposal condition, and may be representative of dredged material from different sources, few faunal differences appear to exist. Results of this study indicate little long-term alteration in community structure and abundance. Control versus disposal site discrimination by taxa since the previous study has been greatly reduced. Likewise, heavy metals impact to the sediment, interstitial water, and benthic community was negligible.

Differences in organism abundance between the control and disposal areas were demonstrated among several key taxa. Since few statistically significant differences were detected, the observed differences may have resulted from one, or a combination of, contributing factors: 1) true site comparability may have been masked by single season sampling, resulting in "snapshot" variation due to natural seasonal succession; 2) benthic communities tend to exhibit natural community patchiness; 3) site specific distribution and composition may simply have been a substrate effect, demonstrating the organism's optimum or preferential location; and/or 4) variation in relative abundance and composition was the direct effect of dredged material disposal. Since no dramatic or critical differences or impact could be shown, the ecological significance of dredged material disposal at the Lake Erie, Ashtabula Harbor, location appears to be minimal. In addition, the disposal areas are comprised of a benthic macroinvertebrate community which shows little difference from the predisposal community, further supporting the assumption of minimal long-term impact.

PREFACE

This report discusses data from environmental samples collected during August 1979 from dredged material disposal sites and nearby reference areas in Lake Erie near Ashtabula, Ohio. Material dredged from Ashtabula Harbor and River was placed at the disposal sites in 1975 and 1976. Long-term impacts were assessed by examination of sediment, animal, and water samples collected from the study area. This same area was investigated during the Dredged Material Research Program, a comprehensive study of dredged material impacts completed in 1978. The data support the conclusion that the overall impact of the disposal operations was minimal.

The investigation was conducted as a part of the Dredging Operations Technical Support (DOTS) Program. The DOTS Program was established by the Office, Chief of Engineers, through the Dredging Division of the Water Resources Support Center, Fort Belvoir, Va. Implementation of DOTS was assigned to the US Army Engineer Waterways Experiment Station (WES), Environmental Laboratory (EL), Vicksburg, Miss. Work at the Lake Erie site was conducted under Contract No. DACW39-79-C-0060 between Roy F. Weston, Inc., West Chester, Pa., and the WES. The author of this report was Dr. Kenneth J. Salamon. Dr. Donald R. Phoenix, Roy F. Weston, Inc., also contributed to the completion of this project.

This study was conducted under the direction of WES principal investigator Dr. Henry E. Tatem, Environmental Research and Simulation Division (ERSD), with the supervision of Dr. Richard K. Peddicord, ERSD, and Mr. Donald L. Robey, Chief, ERSD. Contracting Officer's Representative was Dr. Robert M. Engler, ERSD.

The Dots Program is a part of the EL management unit entitled the Environmental Effects of Dredging Programs (EEDP), Mr. Charles C. Calhoun, Jr., Manager; DOTS coordinator in EEDP is Mr. Thomas R. Patin. Dr. John Harrison is Chief of the EL.

Commanders and Directors at the WES during this study were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

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LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimeters
ounces (U. S. fluid)	29.57353	cubic centimeters

LONG TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

SECTION 1

INTRODUCTION

1.1 BACKGROUND

Ashtabula Harbor, an important coal and ore transshipment center, is located on the south shore of Lake Erie, approximately 80 kilometers east of Cleveland, Ohio. River and harbor dredging has been conducted since 1909 (Sweeney, 1978), with the dredged material disposal in the open waters of the lake. The U.S. Army Corps of Engineers' Dredged Material Research Program (DMRP) selected the Ashtabula disposal site to investigate the short- and long-term effects of disposal in open, freshwater environments. The DMRP study had three principal objectives:

- To evaluate the impact of disposal on biota
- To determine chemical impact of disposal on the water column and sediment
- To assess the stability of dredged material after disposal

Initial aquatic investigation of the Ashtabula disposal site was conducted from June 1975 to September 1976 as DMRP work unit No. 1A08: DMRP Technical Report D-77-42, "Aquatic Disposal Field Investigations, Ashtabula River Disposal Site, Ohio" (Danek, et al., 1977; Sweeney, 1978; Sweeney, 1978_a; Wyeth and Sweeney, 1978).

Initial investigations evaluated the release and impact of dredged material on the pelagic biota (phytoplankton, zooplankton, and fish), and benthic communities. Geochemical, sedimentological, water quality, hydrographic, and bathymetric data supplemented biological analyses. Sampling was conducted at one reference and three disposal areas; eleven water quality stations were situated throughout the study area. The research program began with baseline (predisposal) sampling in the summer of 1975. Disposal event, and 30-, 60-, and 90-day postdisposal sampling was performed during summer and autumn. The 1975 program was repeated in 1976 to assess long-term impacts. In addition, a new disposal event and water quality station were investigated for more intensive short-term monitoring. The present study, designed to assess long-term impacts, was conducted during August 1979.

1.2 ORGANIZATION AND OBJECTIVES OF THE PRESENT STUDY

Investigations designed to follow up the DMRP research program were initiated by the Waterways Experiment Station (WES), under the Disposal Operations Technical Support (DOTS) Program. Sampling stations utilized in this study were defined by results of the DMRP research program. Site selection was based on the potential compatibility of the original data, with data from sample collections planned for the DOTS research program.

The DOTS program at Ashtabula was organized into three specific research tasks:

Task I - Benthic Community Investigations

- Describe community structure, abundance, and biomass in reference (control) and disposal areas

Task I (Cont'd)

- Compare benthic communities in reference and disposal areas

- Summarize results relative to conclusions presented by DMRP

Task II - Substratum Stability Investigations

- Describe sediment relationships between disposal and reference areas

- Evaluate results as related to processes affecting the sediment regime

Task III - Substratum Inorganic Contaminant Investigations

- Quantitate mercury and cadmium concentrations in key benthic invertebrate species

- Quantitate mercury and cadmium concentrations in sediments and interstitial water

- Compare levels of mercury and cadmium between reference and disposal areas

1.3 DESCRIPTION OF THE STUDY AREA

1.3.1 Lake Erie

The study area is located 4-6 km from the south shore of Lake Erie, with shoreline contours running from northeast to southwest (Figure 2-2). Average water depth is 15 to 18 meters throughout the study area. Surface water movement is generally eastward, while offshore bottom waters move toward the southwest (Sweeney, 1978). Currents at the bottom can reach 0.6 m/sec, and are generally higher in summer than winter.

The water column is temperature-stratified from June through September, and isothermal during the rest of the year. The summer thermocline is 15-18 meters below the surface. Thus, the thermocline intersects the lake bottom at depths typical of the study area, and only a thin layer of hypolimnetic water is present. Epilimnion temperatures in summer are greater than 15.6°C, while the hypolimnion temperatures are typically less than 5°C.

Dissolved oxygen in the hypolimnion decreases during stratification, and may drop to zero. In the epilimnion, dissolved oxygen is always near saturation, and varies with weather conditions.

1.3.2 Ashtabula River and Harbor

The Ashtabula River drains an area of 360 km^2 in northeastern Ohio. Average flow is calculated at 4.79 m^3/sec (169 cfs) (Sweeney, 1978). In the town of Ashtabula Harbor the river shoreline is densely occupied by marinas, commercial docks, and transportation facilities. Industrial, municipal, and domestic wastes from the City of Ashtabula are also discharged into the river.

Ashtabula Harbor is formed by stone breakwaters which enclose an area at the mouth of the river, 1.5 km wide and 1 km deep. It is a major coal and ore transshipment center, servicing large Great Lakes bulk carriers. The Buffalo District, U.S. Army Corps of Engineers, conducts a maintenance dredging program in the harbor; river dredging is less frequent.

SECTION 2

MATERIALS AND METHODS

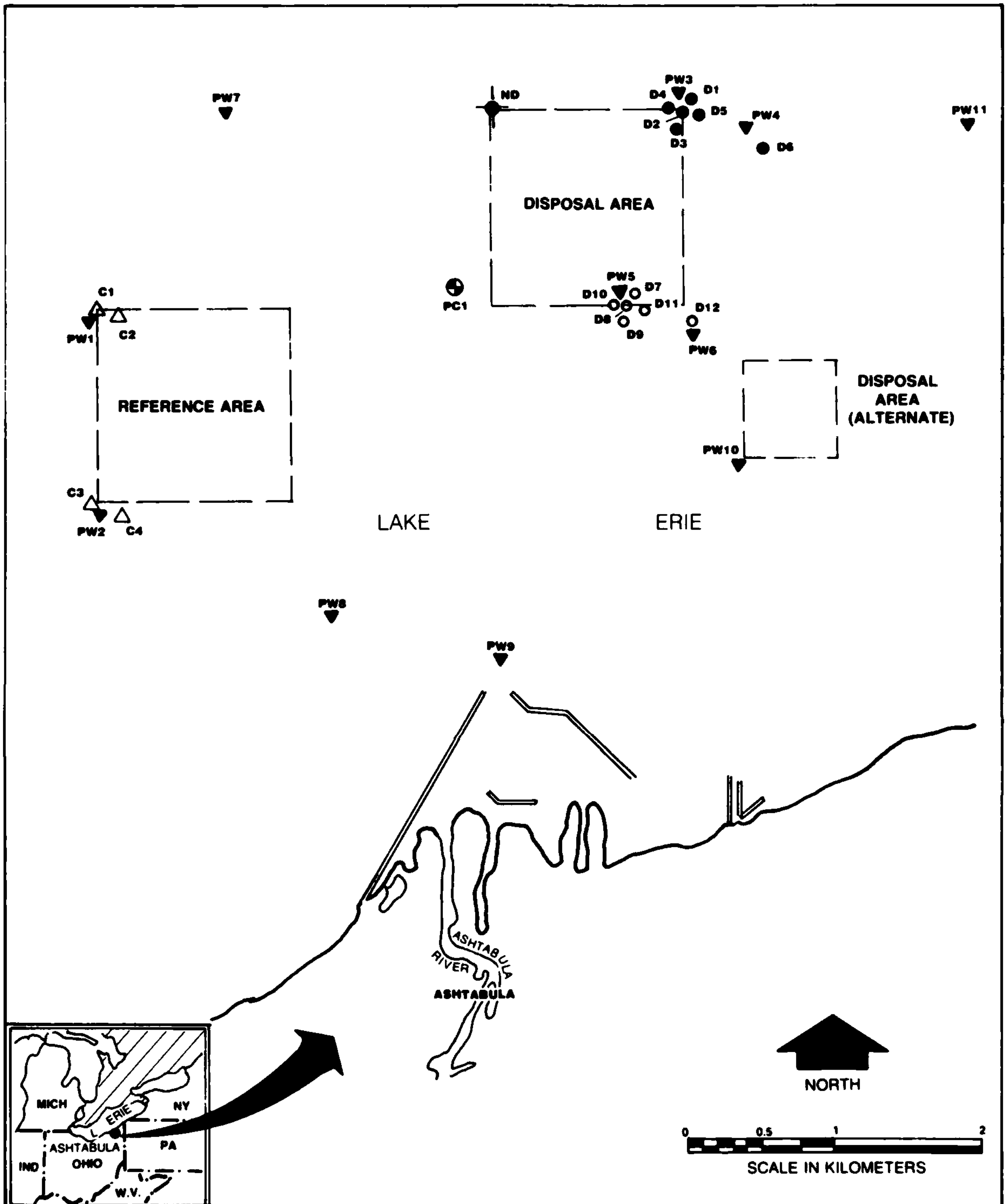
2.1 STATION ORGANIZATION

All sampling sites were contained within sampling areas utilized during the 1975 DMRP study (Figure 2-1). Two sites in the reference area and three in the disposal area were sampled. Figure 2-2 shows those sites sampled in the present study. Numerical designation was assigned based on proximity to previously used sampling sites. The two reference sites were designated C1 and C3, and the three disposal sites designated D2, D8, and ND.

Each site consisted of a quadrilateral measuring approximately $400m^2$, defined by a Mini-Ranger III electronic horizontal positioning unit (see Section 2.2.1). All sites were subdivided into 400 10 X 10 meter quadrilateral stations. Thirty-eight stations were chosen for sampling benthic invertebrates using a random numbers table (see Figures 3-2, 3-6, 3-10, 3-14, and 3-19). Three of the thirty-eight stations, including one as close to the center of the areas as possible, and one close to the previous study station, were chosen for sediment chemistry and water quality sampling. The coordinates at the center of each subdivision were recorded, and every effort was made to maintain the sampling craft within the subdivision.

2.2 SAMPLE COLLECTION

Benthic macrofauna, meiofauna, and sediment samples were collected during August 1979 using a modified Reineck box core sampler.



SAMPLING STATIONS LEGEND

PW1-11 ▼ – WATER QUALITY

D1-D6 ● – ASHTABULA HARBOR DREDGING DISPOSAL AREA-1975

C1-4 △ – REFERENCE AREA

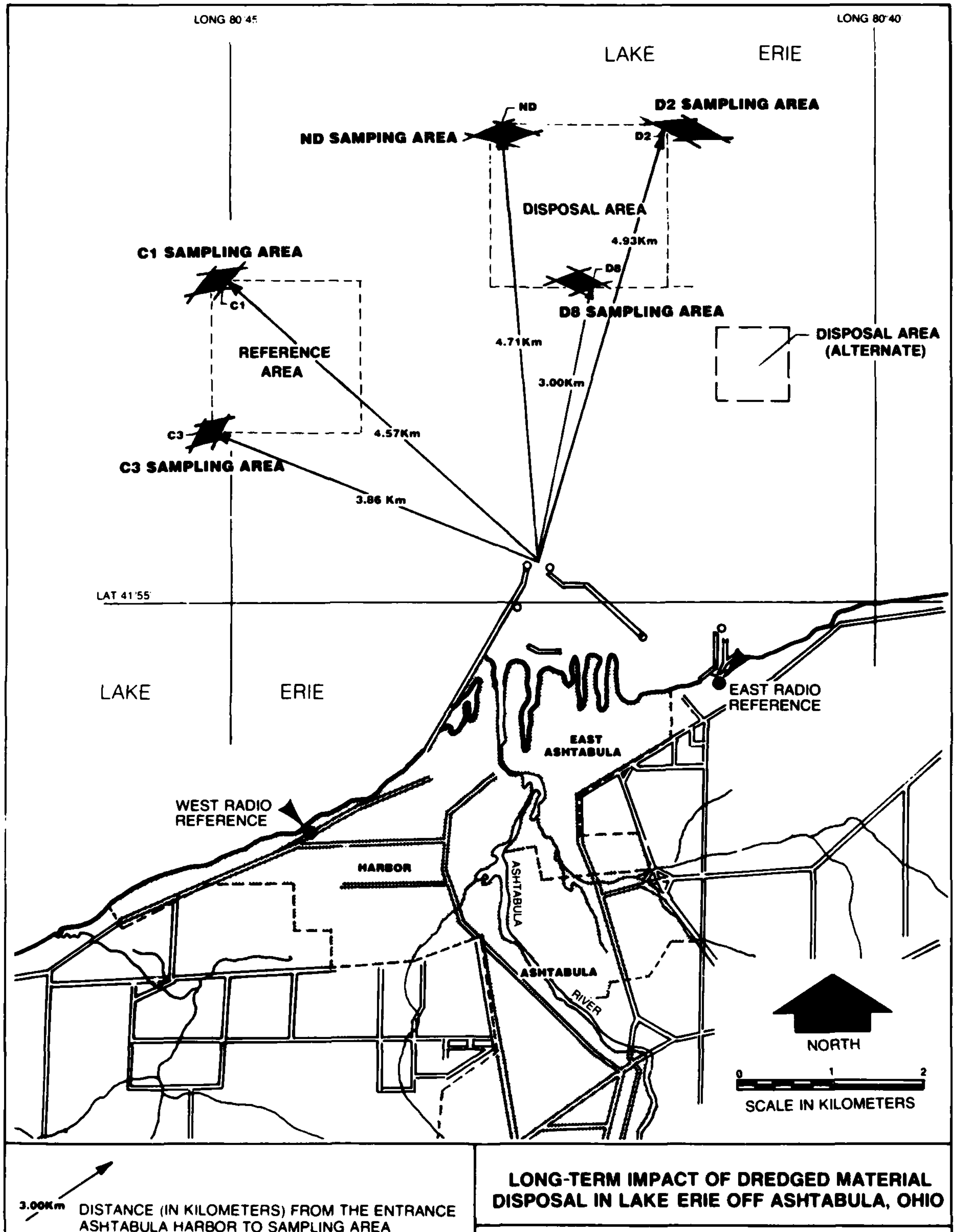
D7-12 ○ – ASHTABULA RIVER DREDGING DISPOSAL AREA-1975

PC1 – CURRENT MEASURING

ND – DREDGING DISPOSAL AREA-1976

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 2-1
MAP OF STATION LOCATIONS - PREVIOUS STUDY



LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 2-2
MAP OF SAMPLING AREAS
- PRESENT STUDY

Construction and operation of the gear are discussed in detail in Farris and Crezee (1976). Core dimensions measured 10 cm x 17 cm x 20 cm, and sampled a surface area of 170 cm^2. The weight of the unit in air is approximately 40 kg; a vertical beam to which the box is attached can be weighted up to approximately 80 kg to increase penetrating power. When the device is cocked, the beam is supported directly by the hoisting wire. As the corer skids touch bottom, relaxation of tension in the wire releases the beam, driving the box into the substratum. Tension applied to the recovery wire in retrieving the device causes a footplate to close off the corer bottom, sealing the box. This ensured sample recovery with little or no washout.

Core samples (3.14 cm^2) were first subsampled for meiofauna by inserting two 2-cm-diameter, 20-cm-long tubes into the box-corer sample. Each meiofauna core was extruded and divided into two horizons (0-10 cm, > 10 cm). The segments were transferred to containers, stained with rose bengal solution, and preserved in 10 percent formalin. An aliquot for grain-size analysis was then scooped from the surface layer and transferred to a plastic bag. The remainder of the core to be used for macrofaunal analysis was extruded, and also divided into 0-10 cm, and >10 cm horizons. Each horizon was sieved through a U.S. Standard #30 screen (500 micron mesh), and all material remaining on the screen preserved in 10 percent formalin.

Three sets of replicate cores for interstital water and sediment analysis of heavy metals content were collected at each station with a Wildco K-B Design Heavy Duty gravity corer. The messenger-activated device collected a 50-cm-long, 2-cm-

diameter core in plastic liners. Corer nose piece, "eggshell" core-catcher, and liner caps were made of plastic to avoid heavy metal contamination. Each sample was removed from the corer in its liner, capped at both ends, and stored frozen until analyzed.

Benthic organisms for heavy metals analysis were collected in bulk using a Ponar bottom grab, at Sites C1 and D2. The animals were separated into groups of oligochaetes and molluscs, held in aquaria until their guts were cleared, then stored frozen until analysis.

Water samples for dissolved oxygen were collected from three depths at each station with a Niskin remote-closing water bottle. Aliquots of 300 ml were fixed with manganous sulfate and alkali-azide reagents, and stored in BOD bottles for later analysis by the Winkler method (Standard Methods, 1976).

Temperature, pH, and specific conductance were measured at three depths at each station with a Martek Mark V Water Quality Analyzer.

Position determination was made by means of a Motorola Mini-Ranger III System. Reference stations were located on shore at the points indicated in Figure 2-2. These reference positions correspond to those established during the previous study. The shipboard station continuously establishes its position by measuring the distance from both reference stations via radio signals. The position of the sampling craft is defined by the intersection of the two curves whose radii are the distances from the reference station.

2.3 SAMPLE PROCESSING

2.3.1 Benthic Macroinvertebrates

Macroinvertebrate samples were processed by picking and sorting the organisms into separate vials, by major taxa. Oligochaetes were mounted on microscope slides for identification; the remaining organisms were examined unmounted. Identification was made to the lowest practicable taxon, and the organisms enumerated. Keys used in the identifications were those contained in Pennak (1978), Edmondson (1959), Brinkhurst and Jamieson (1971), Brinkhurst (1964, 1965, 1966, 1976), and Hiltunen (1970).

2.3.2 Benthic Meiofauna

Benthic meiofauna samples were sieved through 500- and 63-micron mesh screens to separate the organisms from macrofauna, and to decrease sediment loading. The micro-fraction was centrifuged in distilled water, and the supernatant passed through a 63-μ sieve. The resulting pellet was suspended in a colloidal silica (Du Pont Ludox AM) to further separate organisms via a density gradient. The pellet fraction was recentrifuged, and the second supernatent and pellet sieved individually through a 63-μ screen. Each supernatant and pellet was examined microscopically, and all organisms identified and enumerated. In order to remain compatible with abundance data presented by Sweeney (1978), organism numbers are expressed as organisms/m^2, derived from actual surface sample areas of 170 cm^2 and 3.14 cm^2 for macrofauna and meiofauna, respectively.

2.3.3 Sediment

Eight to twelve grams of wet sample were taken from each storage bag and placed in an eight ounce* jar. Twenty milliliters of sodium hexametaphosphate ($(Na PO_3)_6$) were

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* A table of factors for converting U. S. customary units of measurement to metric (SI) is presented on page viii.

added to the jar, which was then filled to within one inch of the top with distilled water. The jar was shaken on a Burrell Wrist Action Shaker for at least forty minutes. The sample was then wet sieved through a 62.5-μ (4 ϕ) sieve separating the coarse fraction (< 4ϕ). The fine fraction was washed into a 1000-milliliter settling tube, and set aside for pipette analysis. The coarse fraction was washed from the sieve into a beaker and dried. The coarse fraction was then brushed out of the beaker onto a nest of 3-inch sieves, ranging in size from -1 to 4 ϕ at 1/2-phi intervals (Table 2-1). The sieve nest was shaken on a Pulverit 3 electromagnetic sieving machine for 10 minutes. The contents of each sieve were then weighed and recorded. Any material that passed through the 4-ϕ sieve (< 4 ϕ) was brushed into the settling tube.

The fine fraction was sized using a standard pipette procedure. Distilled water was added to the sedimentation cylinder to bring the total volume of each cylinder to 1000 ml. The cylinders were vigorously shaken, and a 20-ml aliquot was taken immediately after shaking. Subsequent 20-ml aliquots were taken at depths and times computed from Stoke's Law for particle settling (Table 2-2). Each aliquot was discharged into a previously weighed beaker, dried, and sample weights were recorded.

2.3.4 Heavy Metals

- Interstitial Water and Sediment

The still frozen sediment core was extruded whole from the plastic collection tube. The top 10 cm of sediment from each core was removed and sealed in a plastic bag filled with nitrogen. When the cores were long enough, the lower 10-cm section was likewise cut and sealed. Once

Table 2-1

Grain Size Scales for Sediments

U.S. Standard Sieve Mesh #		Millimeters	Microns	Phi (Ø)	Wentworth Size Class	
		4096		-12		
		1024		-10	Boulder (-8 to -120Ø)	
Use		256		- 8		
wire		64		- 6	Cobble (-6 to -8Ø)	GRAVEL
squares		16		- 4	Pebble (-2 to -6Ø)	
5		4		- 2		
6		3.36		- 1.75		
7		2.83		- 1.5	Granule	
8		2.38		- 1.25		
10		2.00		- 1.0		
12		1.68		- 0.75		
14		1.41		- 0.5	Very coarse sand	
16		1.19		- 0.25		
18		1.00		0.0		
20		0.84		0.25		
25		0.71		0.5	Coarse sand	
30		0.59		0.75		
35	1/2	0.50	500	1.0		
40		0.42	420	1.25		
45		0.35	350	1.5	Medium sand	
50		0.30	300	1.75		SAND
60	1/4	0.25	250	2.0		
70		0.210	210	2.25		
80		0.177	177	2.50	Fine sand	
100		0.149	149	2.75		
120	1/8	0.125	125	3.0		
140		0.105	105	3.25		
170		0.088	88	3.5	Very fine sand	
200		0.074	74	3.75		
230	1/16	0.0625	62.5	4.0		
270		0.053	53	4.25		
325		0.044	44	4.5	Coarse silt	
		0.037	37	4.75		
	1/32	0.031	31	5.0		
	1/64	0.0156	15.6	6.0	Medium silt	
Analyzed	1/128	0.0078	7.8	7.0	Fine silt	MUD
by	1/256	0.0039	3.9	8.0	Very fine silt	
		0.0020	2.0	9.0		
Pipette		0.00098	0.98	10.0	Clay	
		0.00049	0.49	11.0		
or		0.00024	0.24	12.0		
		0.00012	0.12	13.0		
Hydrometer		0.00006	0.06	14.0		

Table 2-2

Pipette Schedule for Fine (<62 μ) Fraction

Based on Stoke's Law at 25°C

Stoke's Law

Size Finer Than	Depth	Time	Settling Velocity cm/sec
4ø	20	0:00:20	$3.9265 \cdot 10^{-1}$
5ø	20	0:03:22	$9.9010 \cdot 10^{-2}$
6ø	10	0:06:45	$2.4691 \cdot 10^{-2}$
7ø	10	0:27:01	$6.1690 \cdot 10^{-3}$
8ø	10	1:48:04	$1.5423 \cdot 10^{-3}$
	5	0:54:02	
9ø	10	7:12:--	$3.8580 \cdot 10^{-4}$
	5	3:36:--	
10ø	10	28:50:--	$9.6339 \cdot 10^{-5}$
	5	14:25:--	
11ø	5	57:38:--	$2.4099 \cdot 10^{-5}$

the core samples thawed, they were placed in 8-oz. jars, sealed in a nitrogen atmosphere and spun in an IEC centrifuge at a speed of 3000 R.P.M. for at least 60 minutes. Fractions were processed under a nitrogen atmosphere to prevent changes in chemical state due to oxidation. Interstitial water was decanted from the sample jars and sealed in acid-cleaned Nalgene tubes. Dewatered sediment was extracted and stored in plastic envelopes. All samples were refrigerated until analyses of heavy metal content could be performed.

Analysis for total mercury was performed using nitric/sulfuric acid digestion and flameless (cold vapor) atomic absorption techniques, as outlined in the EPA Manual of Methods for Chemical Analysis of Water and Wastes (EPA-625-/6-74-003a, 1976). Absorbance (peak height) was measured as a function of mercury vapor radiation at 253.7 mm, on a Perkin-Elmer 503 atomic absorption spectrophotometer.

Total cadmium was determined by digestion with concentrated nitric acid and a graphite furnace atomic absorption technique, as outlined in the EPA Manual of Methods for Chemical Analysis of Water and Wastes (EPA-625-/6-74-003a, 1976). Cadmium absorbance (peak height) was measured at 228.8 mm on a HGA 2100 graphite furnace atomic absorption spectophotometer (Germany). Results are expressed as ng metal/ml interstitial water, and ng metal/g dry weight of sediment sample.

- <u>Benthic Organisms</u>

Mercury and cadmium tissue burdens were determined for molluscs, and for cadmium only in oligochaetes. The organisms were grouped by taxa for control and disposal areas to provide adequate biomass. Metals analysis was performed in replicate for each group according to the methods cited above. Results are expressed as ng metal/mg dry wt of sample.

2.4 DATA ANALYSIS

2.4.1 Sediment

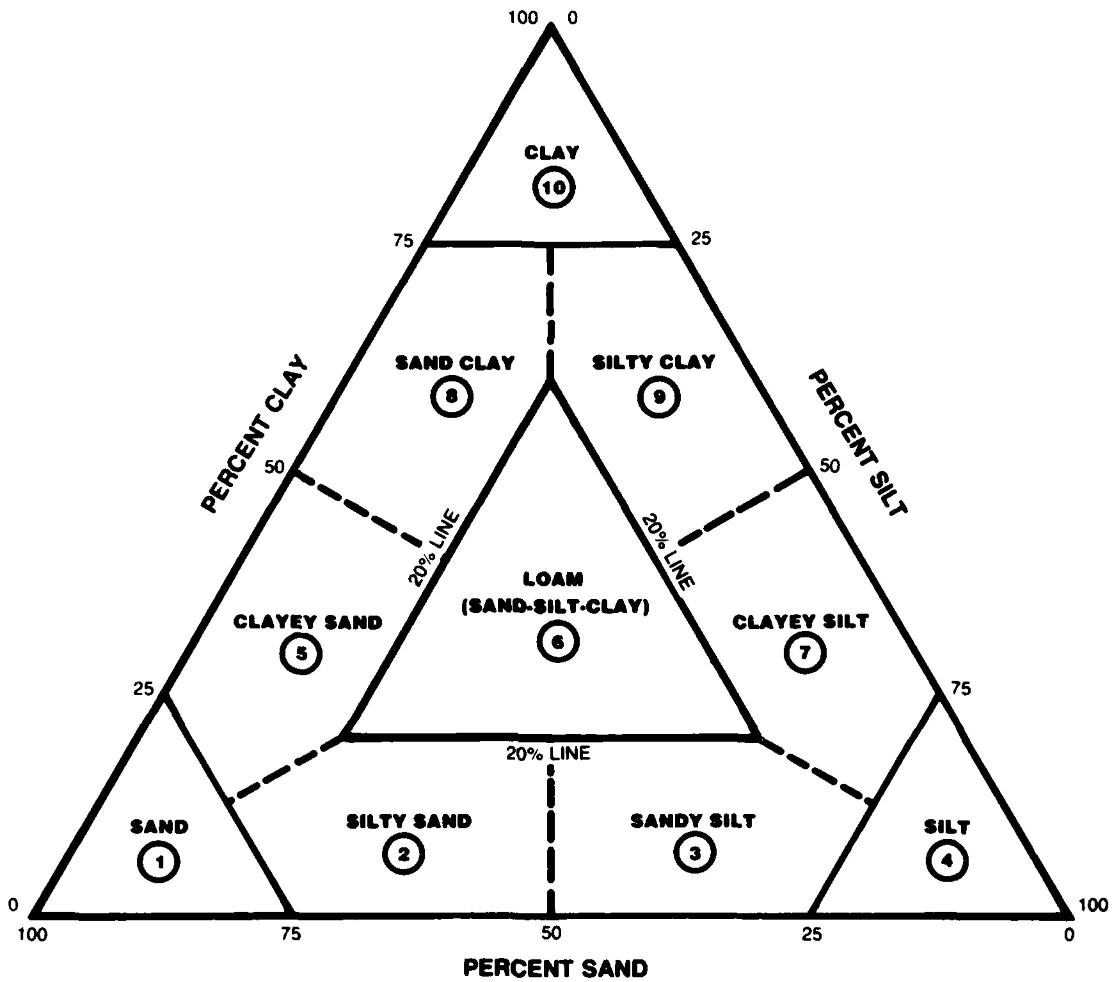
Size distribution analyses were conducted on the sediment sieve and pipette data using the SEDAN computer program (Creager, et al., 1962). This generated several statistical parameters (see Appendix A). One such parameter was the Shepard Class, a sediment classification based on textural characteristics and used in sediment/organism association analysis. Shepard Class is based on the weight-percent content of sand, silt, and clay in individual sediment samples. The grain size, or type, is defined by the Wentworth particle size distribution scheme (Table 2-1). Under this system, sand is defined as a particle with a mean diameter between 2000 μ and 62.5 μ; silt as a particle ranging from 62.5-3.9 μ; and clay as finer than 3.9 μ. All of the gradations of particle sizes are linked by a factor of 2, resulting in a geometric size-grade scale called the phi (ϕ) scale. Phi is the logarithm to the base 2 of the particle size in millimeters.

The functional basis of the computed Shepard Class is demonstrated by a ternary diagram, in which sand, silt, and clay are represented at the apices (Figure 2-3). Numerical ranking is assigned according to the relative percent occurrence of each sediment type.

2.4.2 Benthic Organisms

A commonly used diversity index (H), proposed by Brillouin (1962), was used to determine organism diversity, per site, in both sample horizons of the control and disposal areas:

$$H = \frac{1}{N} \log_2 \frac{N!}{n_1!\, n_2! \ldots n_s!}$$



SOURCE: ORIGINAL REFERENCE: SHEPARD F.P.; 1954

5 NUMERICAL RANKING ASSIGNED ACCORDING TO THE RELATIVE PERCENT OCCURRENCE OF EACH SEDIMENT TYPE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 2-3
SHEPARD TEXTURAL CLASSIFICATION SCHEME

where:

H = diversity index value

N = total number of individuals

s = total number of taxa

n_i = number of individuals in taxon i where

$i = 1, 2, \ldots, s$

This index is relatively independent of sample size, yet is sensitive to both the number of taxa present and the number of individuals in each taxon (Pielou, 1969; Poole, 1974).

Other data analyses were performed on the upper horizon organism abundance data using the Statistical Analysis System (SAS) (Service, 1979). These analyses included two-way analyses of variance (ANOVA), correlation analyses, cluster analyses, and several graphical association techniques.

Correlation analyses were attempted between organism abundance data and sediment data. Both abundance and sediment values were transformed using logarithmic, arcsine, square root, and fourth root transformations to linearize the data to attempt to define relationships between the sediment and organism distributions (Sokal and Rohlf, 1969).

Cluster analyses were also attempted on the whole organism abundance data set, as well as a subset of this data set. This balanced data set was created by selecting the same number of sites per area with similar sediment characteristics.

The similar sediment subsetting criteria were defined as being in Shepherd Class 6 and 7. The purpose of this procedure was to create a data set that could be analyzed with the removal of some of the confounding factors due to sediment differences. Since area ND had such dissimilar sediments, it was not possible to include this area in the subsetted data set.

ANOVA's were performed on both the whole data set and the subsetted data set for both organism abundance per site and number of taxa per site. Several transformations (square root, fourth root, and $\log_{10}$) were examined to determine which would most adequately transform the data so that the assumptions of ANOVA would be met (Elliot, 1977). It was determined that the $\log_{10}$ transformation adequately stabilized the variance (Green, 1979); therefore, the abundance data were transformed using a $\log_{10}$ (X+1) transformation.

SECTION 3

RESULTS

3.1 SAMPLE COLLECTIONS

Sampling, scheduled to begin on 11 August 1979, was delayed two days by strong winds and heavy seas. Marginal weather conditions persisted throughout most of the sampling period. This precluded the collection of the planned thirty-eight samples/site. Since thirty-eight sampling locations had previously been designated by a random numbers technique, actual sample stations were assigned from this group.

The presence of rock and shale scattered throughout much of the disposal area severely impacted sample collections. Many box-core samples were adequate only for analysis of the upper 10cm horizon. In addition, a number of samples, particularly in disposal site ND, were discarded in the field, due to the predominance (or exclusive occurrence) of stone collected in the box-core sampler. No data are available from these samples since the 10-30% sediment present with the stone was not comparable to other samples.

3.2 SEDIMENT ANALYSIS

Characterization of the grain-size scales for sediments was presented previously in Table 2-1. Based on phi interval dissociation, four major grain types were identified in the samples: gravel, sand, silt, and clay. For this analysis, gravel particles are defined as those coarser than -1.0 phi units, sand particles defined as those between -1.0 and 4.0 phi units, silt between 4.0 and 8.9 phi units, and clay particles as those finer than 8.9 phi units.

A summary of the grain-size analysis performed on each sample is presented in Appendix A. This summary includes tabulation of the size intervals measured, Shepard Class, the weight of sediment retained in each size range, and both the fraction and cumulative percentages retained for each size fraction. Statistical parameters calculated for each sample are presented with the enumeration data.

Tables 3-1 to 3-5 present a tabulation of grain-size distributions by relative percentage for each sample station. These data are also summarized in the Tables as the mean ± SD grain-size percentage, and range of values measured, for all samples within each area. Tables 3-1 and 3-2 break out anomalous values in C1 and C3, respectively, to reduce the scatter, and to provide a more accurate representation of the area.

The sand, silt, and clay content of all samples within each area is depicted on ternary diagrams (Figures 3-1, 3-5, 3-9, 3-13, 3-18), in which each vertex represents either the sand, silt, or clay fractions. Each sediment sample appears as a single mark on the diagram, and collectively present the uniformity or scatter of the area grain-size distribution.

In addition to the ternary diagrams, the spatial distributions of percent sand, silt, and clay were mapped individually (Figures 3-2 to 3-21, inclusive). Isopleths of each grain size by percent occurrence show the topographic distribution. In the disposal areas, sedimentation and winnowing effects of the discharged material are obvious.

The variability and heterogeneity of the substrate, both within and between study areas, precluded sampling of strictly comparable stations between sites. Although similar types of substrates existed in each of the sampling areas, other physical variables

such as the thickness and location of origin of dredged material, limited direct comparison. Selection of sampling sites was broad-based and randomized to collect the major sediment types, and to show whether they supported distinctly different faunal assemblages.

3.2.1 Control Area Cl

- Grain Size Characteristics

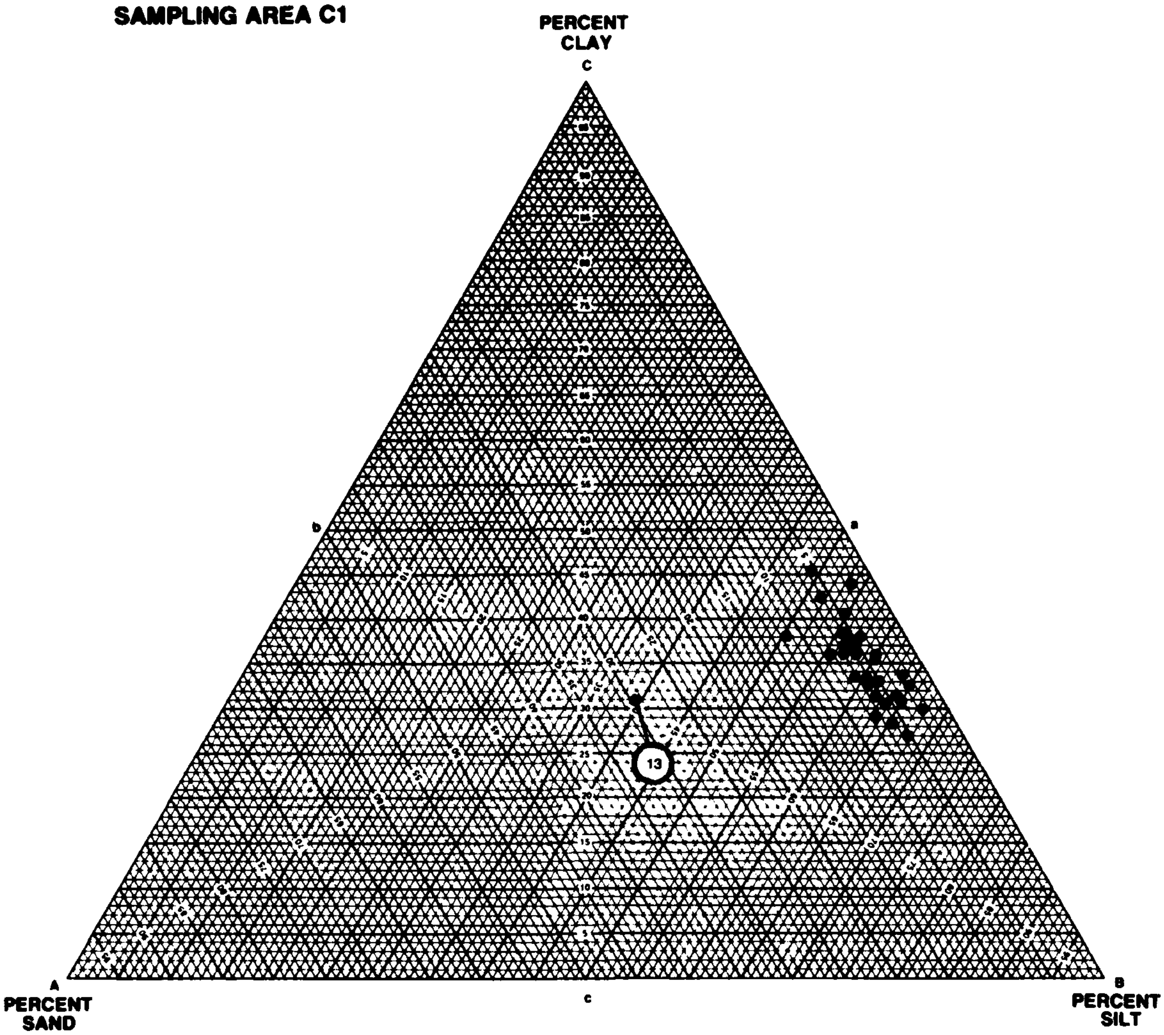
Sediment core samples were collected from thirty locations within the Control Area Cl grid. These sampling stations were located randomly througout the area providing representative geographic sampling throughout the sample area.

The sand, silt, and clay content of each of the thirty samples is depicted in a ternary diagram (Figure 3-1). The plotted samples exhibit a narrow range of textural variation with the exception of sample Cl-13. This sample plots distinctly apart from the rest, reflecting an anomalously high sand content. The range of grain-size distribution among all the samples in comparison with sample Cl-13 is summarized in Table 3-1.

It is apparent that sample Cl-13 contains a coarse-grained admixture of undetermined origin. Because it comprises a single anomalous value in a field of otherwise texturally uniform sediments, the sample can be discounted as representative of Control Area Cl.

- Grain-Size Distribution

The spatial distributions of percent sand, percent silt, and percent clay are presented as individual isopleths (Figures 3-2, 3-3, and 3-4, respectively). The anomalous values from sample Cl-13 were excluded from this analysis. Since the range of percent gravel was so limited, the spatial distribution of this sediment fraction was not mapped. No apparent



NOTE: EACH POINT ON THE DIAGRAM REPRESENTS THE PERCENT GRAIN-SIZE DISTRIBUTION OF A SINGLE SEDIMENT SAMPLE


SAMPLE OUTLIER

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-1
TERNARY DIAGRAM OF SEDIMENT GRAIN-SIZE FRACTIONS — SAMPLING AREA C1

Table 3-1

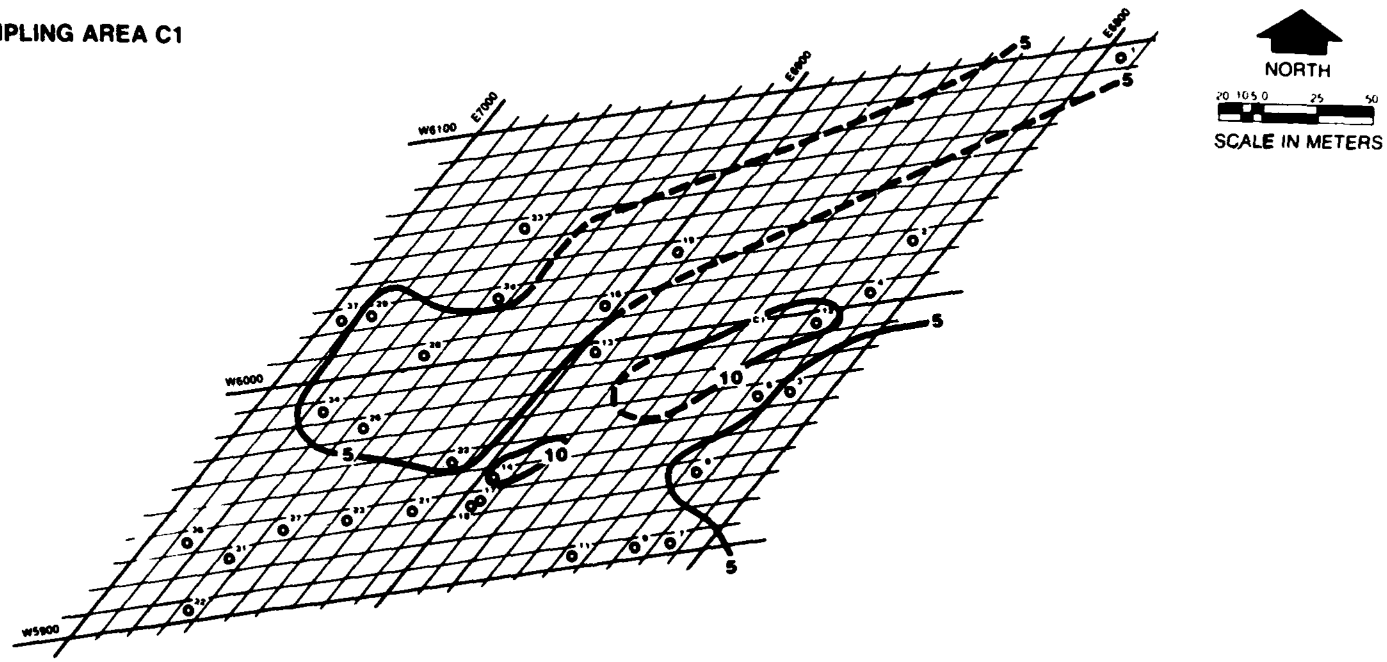
Grain-Size Distribution of Control Area C1

Mean ± Standard Deviation, Range of Sediment Samples, and

Comparison with Sample C1-13

Sample No.	Gravel	Sand	Silt	Clay
	Percent Sediment			
C1-01	0.0	2.3	53.7	44.0
C1-02	0.4	5.6	57.5	36.5
C1-03	0.0	4.8	57.2	38.0
C1-04	0.0	8.2	55.8	36.0
C1-06	0.1	5.4	67.9	26.6
C1-07	0.0	5.5	49.2	45.3
C1-08	0.5	4.6	60.3	34.6
C1-09	0.0	7.1	57.0	35.9
C1-11	0.5	5.7	63.6	30.2
C1-12	0.0	11.5	50.3	38.2
C1-13	0.0	29.7	39.3	31.0
C1-14	0.0	12.2	59.2	28.6
C1-16	0.0	4.4	55.0	40.6
C1-17	0.0	6.1	55.5	38.4
C1-18	0.0	6.0	51.8	42.2
C1-19	0.4	2.5	64.5	32.6
C1-21	0.0	5.6	56.9	37.5
C1-22	0.0	2.9	67.4	29.7
C1-23	0.0	7.5	63.4	29.1
C1-24	0.5	6.1	60.2	33.2
C1-26	0.0	4.0	60.4	35.6
C1-27	1.2	6.4	56.3	36.2
C1-28	0.1	4.2	64.9	30.8
C1-29	0.0	4.4	64.3	31.3
C1-31	0.0	6.4	65.3	28.3
C1-32	0.0	6.0	57.8	36.2
C1-33	0.0	6.1	62.5	31.4
C1-34	0.0	2.7	63.7	33.6
C1-36	0.0	6.0	60.6	33.4
C1-37	0.0	5.5	61.7	32.8
All Samples Mean ± SD	0.1 ± 0.3	6.5 ± 4.9	58.7 ± 6.1	34.6 ± 4.7
(n)	30	30	30	30
Range	0.0 - 1.2	2.5 - 29.7	39.3 - 67.9	26.6 - 45.3
All Samples Excluding C1-13 Mean ± SD	0.1 ± 0.27	5.7 ± 2.2	59.4 ± 4.9	34.7 ± 4.7
(n)	29	29	29	29
Range	0.0 - 1.2	2.5 - 12.2	49.2 - 67.9	26.6 - 45.3

SAMPLING AREA C1

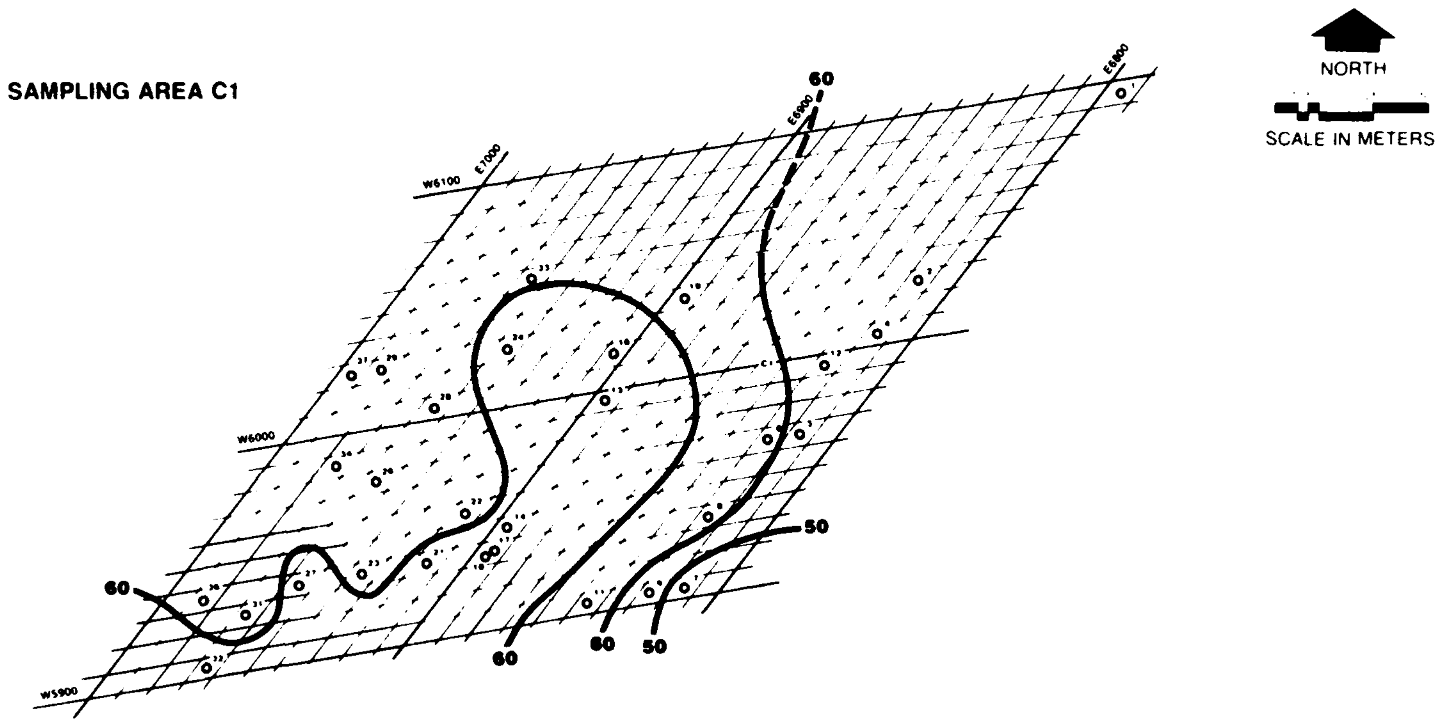


NOTE THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE IN-FIELD CURVED LINE PLOT (SEE FIGURE 2-2)

o 10	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SAND IN SEDIMENT SAMPLES (INTERVALS OF 5 PERCENT) – BROKEN LINES REPRESENT EXTRAPOLATED VALUES

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-2
ISOPLETHS OF PERCENT SAND IN SEDIMENT – SAMPLING AREA C1



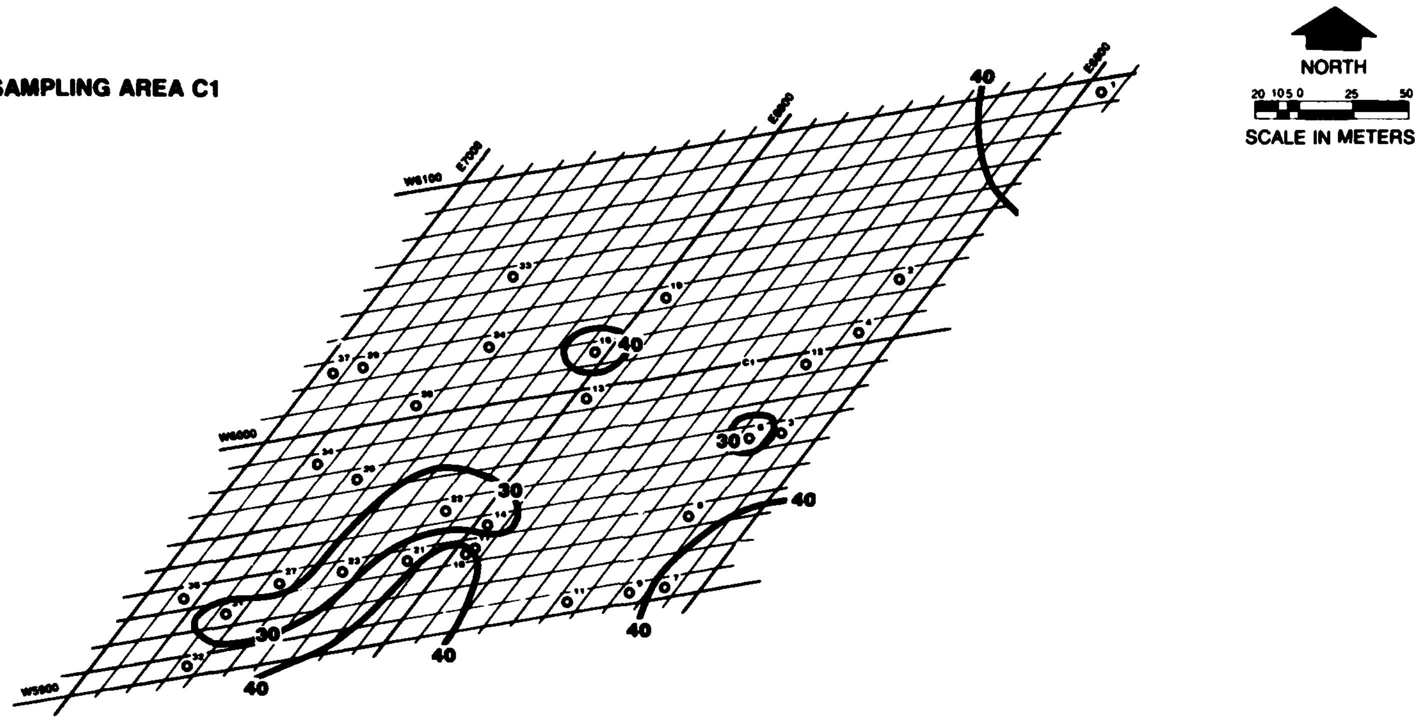
NOTE THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE IN-FIELD CURVED LINE PLOT (SEE FIGURE 2-2)

o[10]	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SILT IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT) — BROKEN LINES REPRESENT EXTRAPOLATED VALUES

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-3
ISOPLETHS OF PERCENT SILT IN SEDIMENT — SAMPLING AREA C1

SAMPLING AREA C1



NOTE: THIS PLAN VIEW OF THE SAMPLING AREA
IS SHOWN AS A STRAIGHT LINE REPRESENTATION
OF THE TRUE IN-FIELD, CURVED LINE PLOT
(SEE FIGURE 2-2)

•	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT CLAY IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-4
ISOPLETHS OF PERCENT CLAY IN SEDIMENT — SAMPLING AREA C1

patterns can be discerned, which would suggest the action of unique physical processes controlling the sediment distribution.

3.2.2 Control Area C3

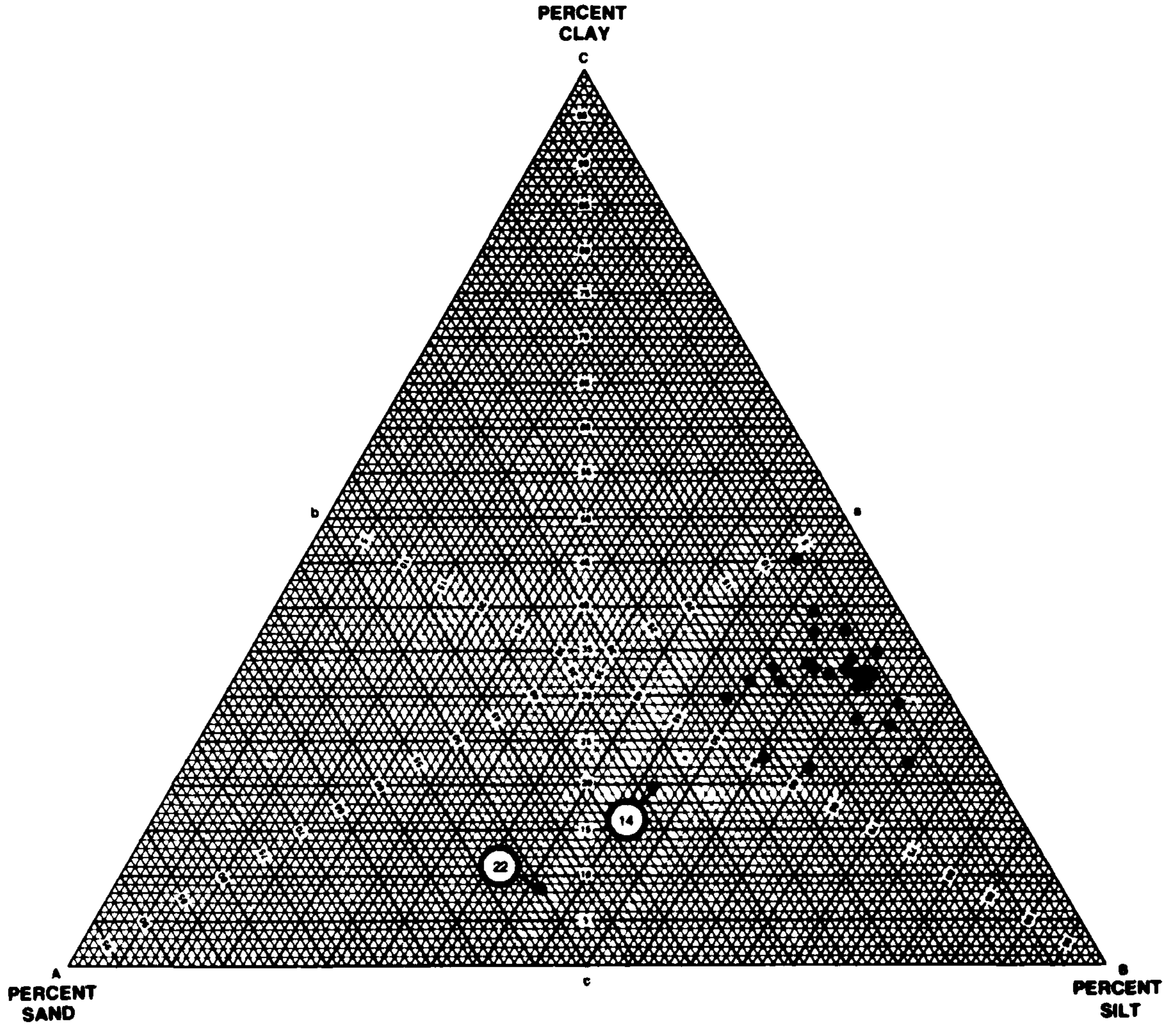
- Grain-Size Characteristics

Analysis of the 29 sediment samples collected from control area C3 showed a fairly narrow range of grain-size distributions with the exception of the sand fraction. The sand fraction varies by roughly 45 percent over all the samples. This is primarily the result of two samples with extremely high sand content. Exclusion of these samples reduces the range of variability within the sand fraction to approximately 17 percent. High gravel content in sample C3-07 was assumed to be anomalous, and not considered in these analyses.

A ternary diagram (Figure 3-5) graphically presents the sand, silt, and clay fractions of each sediment sample. Although slightly more scatter is apparent, the sediment distribution is similar to that of area C1, and illustrates the trend within control areas for a small range in textural variation. The two high-sand samples, when plotted, lie well outside the area of the remaining 27 samples. One sample (C3-14) contains a similar silt-clay ratio accompanied by the admixture of sand. The other, sample C3-22, lies well outside the general range of silt-clay content for this site's sediment, suggesting a different origin.

A summary of the grain-size fractions of the control area C3 samples, together with the anomalous values, is presented in Table 3-2.

SAMPLING AREA C3



NOTE EACH POINT ON THE DIAGRAM REPRESENTS THE PERCENT GRAIN-SIZE DISTRIBUTION OF A SINGLE SEDIMENT SAMPLE

SAMPLE OUTLIER

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-5
TERNARY DIAGRAM OF SEDIMENT GRAIN-SIZE FRACTIONS — SAMPLING AREA C3

Table 3-2

Grain-Size Distribution of Control Area C3

Mean ± Standard Deviation, Range of Sediment Samples, and

Comparison with Samples C3-14 and C3-22

	Percent Sediment			
Sample No.	Gravel	Sand	Silt	Clay
C3-02	0.6	18.8	49.9	30.7
C3-03	1.4	11.8	54.8	32.0
C3-05	0.0	17.7	60.0	22.3
C3-06	0.0	7.9	60.9	31.2
C3-07	8.6	7.2	52.1	32.1
C3-08	0.0	15.7	51.3	33.0
C3-10	0.0	7.9	69.5	22.6
C3-11	0.0	7.1	47.8	45.1
C3-12	0.5	11.6	55.3	32.6
C3-14	0.0	33.4	46.5	20.1
C3-15	0.1	7.1	58.4	34.4
C3-16	0.0	4.8	60.3	34.9
C3-17	0.3	8.0	59.3	32.4
C3-19	0.0	10.1	62.2	27.7
C3-20	0.0	21.5	55.4	23.1
C3-21	0.0	8.8	52.3	38.9
C3-22	0.0	50.8	41.2	8.0
C3-24	0.0	8.1	60.8	31.1
C3-25	0.2	6.2	61.0	32.6
C3-26	0.0	6.3	56.2	37.5
C3-28	0.0	10.3	57.3	32.4
C3-29	0.0	15.5	53.0	31.5
C3-30	0.0	9.4	53.4	37.2
C3-31	0.0	6.8	60.8	32.4
C3-33	0.0	21.8	48.6	29.6
C3-34	0.0	8.9	58.1	33.0
C3-35	0.0	5.3	65.7	29.0
C3-36	0.0	7.7	60.6	31.7
C3-38	0.0	7.3	65.9	26.8
All Samples Mean ± SD	0.4 ± 1.6	12.5 ± 9.7	56.5 ± 6.3	30.5 ± 6.8
(n)	29	29	29	29
Range	0.0 - 8.6	5.3 - 50.8	41.2 - 69.5	8.0 - 45.1
All Samples Excluding C3-14 and C3-22 Mean ± SD	0.4 ± 1.7	10.4 ± 4.9	57.4 ± 5.4	31.8 ± 4.9
(n)	27	27	27	27
Range	0.0 - 8.6	5.3 - 21.8	47.8 - 69.5	22.3 - 45.1

As shown in Table 3-?, exclusion of the two anomalous samples greatly reduces the variability of each size class. Since samples C3-14 and C3-22 differ so greatly, they are not considered representative of sediment conditions in control area C3. The remaining sample values, with their narrow range of grain sizes, indicate a limited range of sedimentation processes occurring over this site.

- Grain-Size Distribution

The spatial distributions of grain sizes within the sediment samples from control area C3 are shown in Figures 3-6, 3-7, and 3-8. There are no regular patterns of sediment texture which could be related to unique sedimentation mechanisms. The site appears free of artificial effects and, therefore, represents a typical control area.

3.2.3 Disposal Area D2

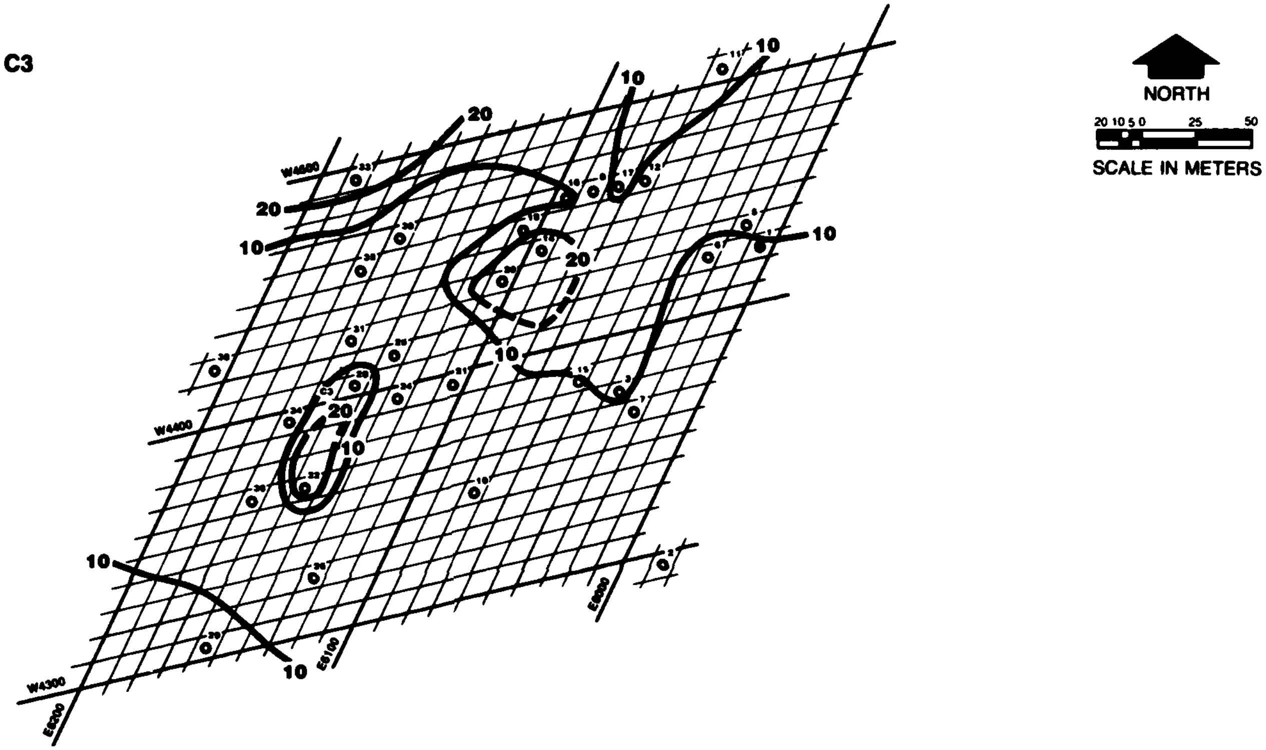
- Grain-Size Characteristics

Twenty-eight sediment samples were randomly collected from disposal area D2. The results of the grain-size analysis are summarized in Table 3-3.

As shown in the table, the range of values for all the sediment samples represents a wide continuum of grain-size distribution in comparison with the narrow range of grain sizes in the samples from both control areas. Disposal area D2 samples range texturally from clayey silts to clean, medium-grained sands.

This scattered pattern is obvious in the ternary diagram (Figure 3-9) which shows a predominent silt-clay fraction intermixed with sand. The gravel fraction represented less

SAMPLING AREA C3



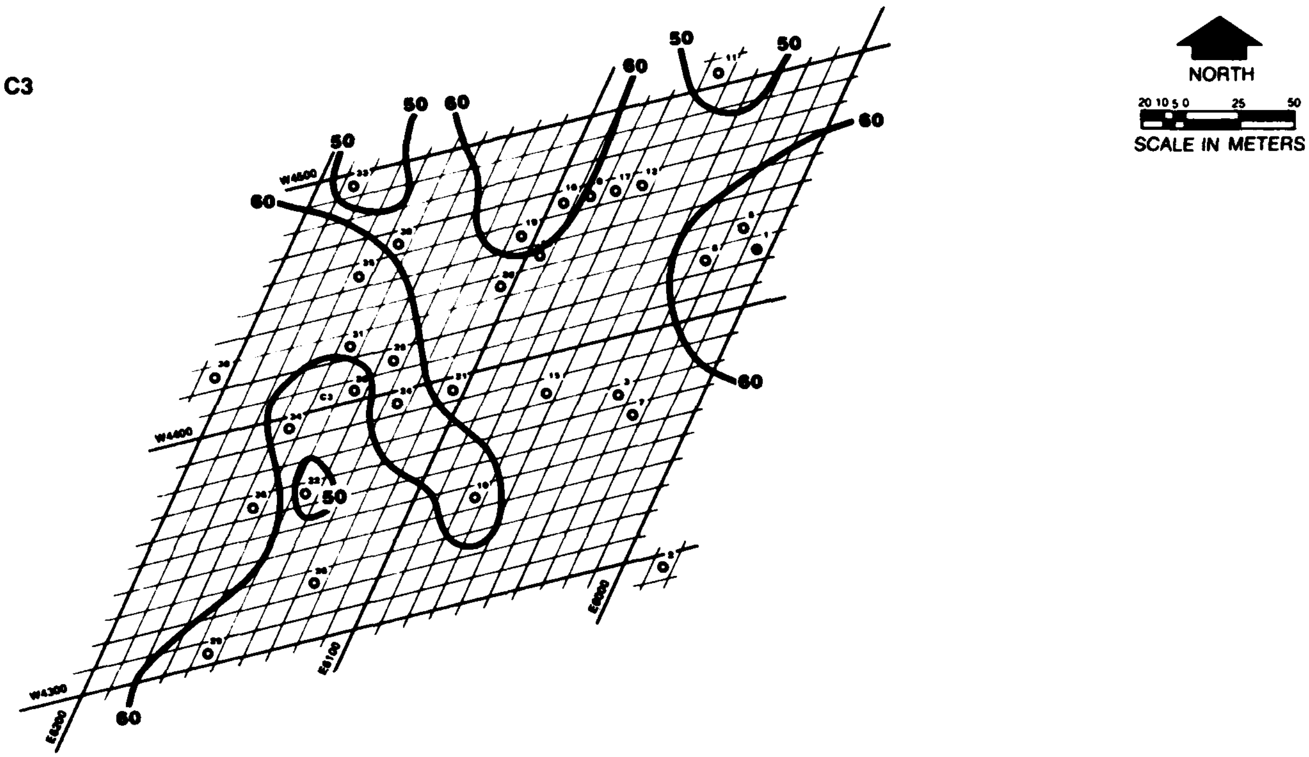
NOTE: THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2)

o[14]	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SAND IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT) – BROKEN LINES REPRESENT EXTRAPOLATED VALUES
●	INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-6
ISOPLETHS OF PERCENT SAND IN SEDIMENT — SAMPLING AREA C3

SAMPLING AREA C3



NOTE THIS PLAN VIEW OF THE SAMPLING AREA
IS SHOWN AS A STRAIGHT LINE REPRESENTATION
OF THE TRUE IN-FIELD, CURVED LINE PLOT
(SEE FIGURE 2-2)

LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION

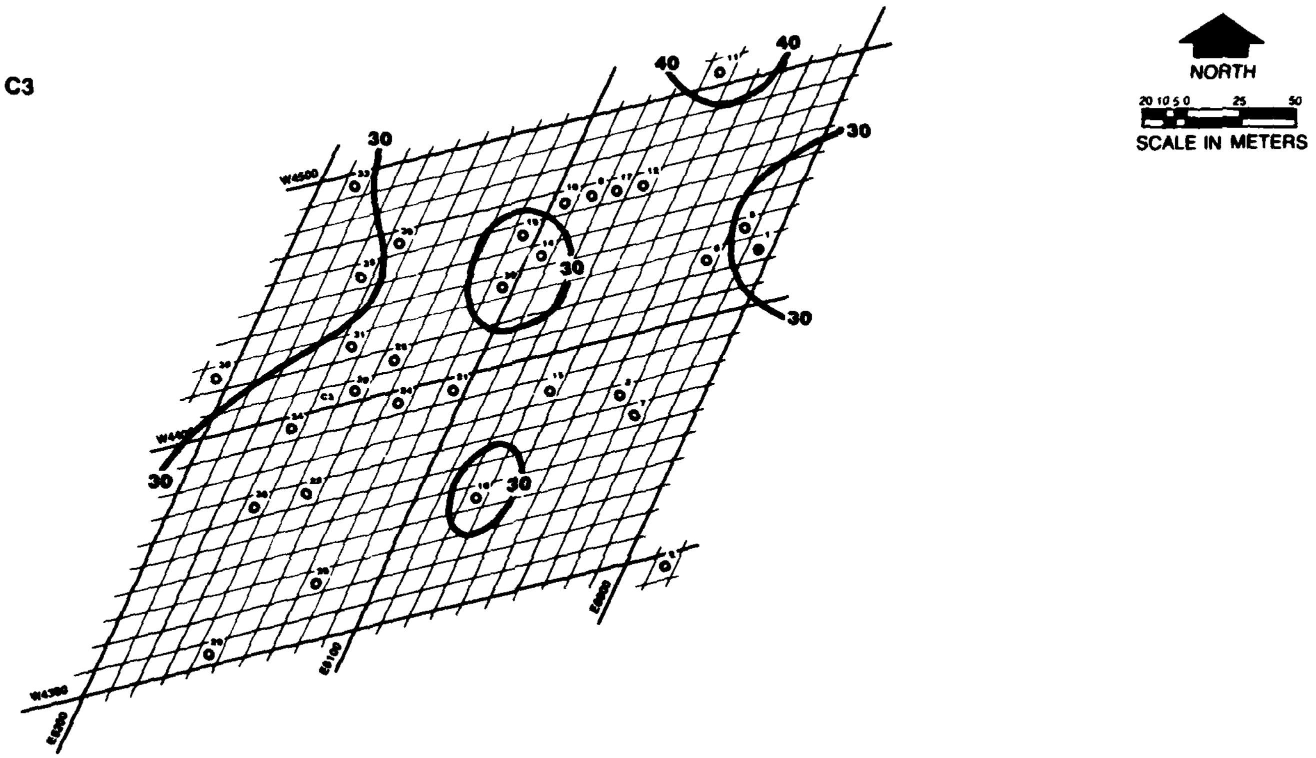
20 ISOPLETH OF PERCENT SILT IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)

● INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-7
ISOPLETHS OF PERCENT SILT IN SEDIMENT — SAMPLING AREA C3

SAMPLING AREA C3



NOTE: THIS PLAN VIEW OF THE SAMPLING AREA
IS SHOWN AS A STRAIGHT LINE REPRESENTATION
OF THE TRUE IN-FIELD, CURVED LINE PLOT
(SEE FIGURE 2-2)

- LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
- 20 ISOPLETH OF PERCENT CLAY IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)
- INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

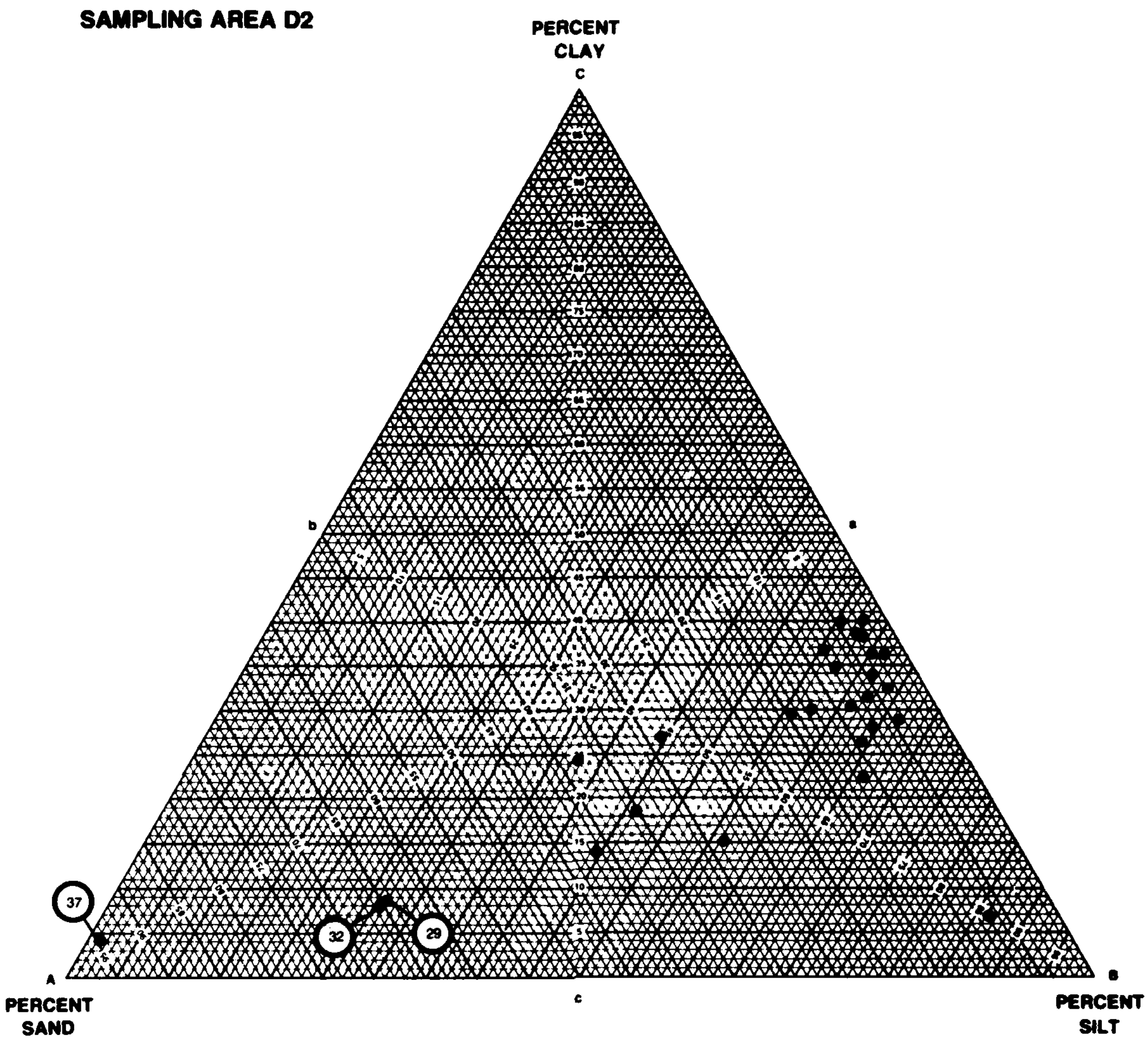
FIGURE 3-8
ISOPLETHS OF PERCENT CLAY IN SEDIMENT — SAMPLING AREA C3

Table 3-3

Grain-Size Distribution of Disposal Area D2

Mean ± Standard Deviation and Range of Sediment Samples

		Percent Sediment		
Sample No.	Gravel	Sand	Silt	Clay
D2-02	0.0	6.3	62.0	31.7
D2-03	0.0	3.1	58.6	38.3
D2-04	0.0	4.8	55.5	39.7
D2-05	0.0	2.7	61.1	36.2
D2-07	0.0	8.2	61.5	30.3
D2-08	0.0	3.6	58.0	38.4
D2-09	0.0	3.8	63.5	32.7
D2-10	0.0	3.2	60.3	36.5
D2-12	0.0	4.5	61.7	33.8
D2-13	0.0	12.1	57.6	30.3
D2-14	0.0	2.2	57.9	39.9
D2-15	0.0	7.1	85.7	7.2
D2-17	0.0	7.9	57.2	34.9
D2-18	0.0	4.2	67.0	28.8
D2-19	0.0	7.8	64.4	27.8
D2-20	0.0	9.2	64.2	26.6
D2-22	0.0	8.0	55.4	36.6
D2-23	0.0	28.7	44.4	26.9
D2-24	1.4	37.9	37.5	23.2
D2-27	0.0	35.2	46.4	18.4
D2-29	0.0	64.5	26.9	8.6
D2-30	0.0	11.0	66.3	22.7
D2-32	0.1	65.5	26.7	7.7
D2-33	0.0	14.5	56.0	29.5
D2-34	0.0	28.3	56.7	15.0
D2-35	0.6	41.4	44.5	13.5
D2-37	0.7	94.9	1.0	3.4
D2-38	3.7	43.7	39.9	12.7
All Samples Mean ± SD	0.2 ± .7	20.2 ± 23.6	53.5 ± 16.1	26.1 ± 11.1
(n)	28	28	28	28
Range	0.0 - 3.7	2.2 - 94.9	1.0 - 85.7	3.4 - 39.9



NOTE: EACH POINT ON THE DIAGRAM REPRESENTS THE PERCENT GRAIN-SIZE DISTRIBUTION OF A SINGLE SEDIMENT SAMPLE

 KEY SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

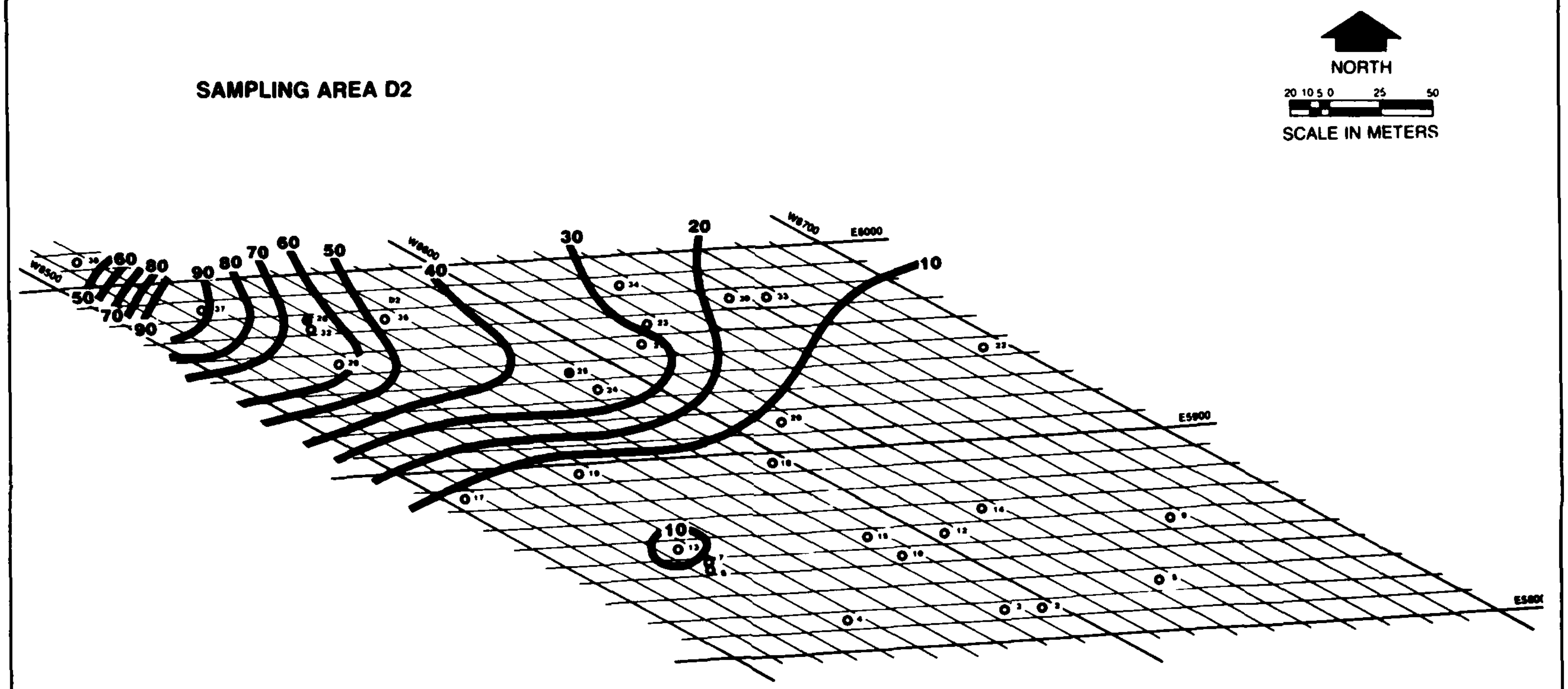
FIGURE 3-9
TERNARY DIAGRAM OF SEDIMENT GRAIN-SIZE FRACTIONS — SAMPLING AREA D2

than four percent of any one sample. Those with gravel components were normalized for sand, silt, and clay content. The majority of samples are clustered along the silt-clay axis; other points are scattered across the diagram trending toward the sand vertex. Significantly, the silt-clay ratio of these scattered points falls within a narrow range which coincides with the silt-clay ratio on the clustered samples.

The range of sediment grain sizes is indicative of a disposal type area. The clayey-silt fraction of each sample reflects the texture of either the natural substrate, or sediment distribution via winnowing of dredged material similar to that of the lake bottom. The heavier sand components (Samples 37, 32, 29), on the other hand, are anomalous, and appear to be the result of dredged material deposition independent in time and location of origin from the lighter D2 fractions. Although sand fractions comparable to those found at D2 were noted during the 1976 study, comparisons based on control and disposal area data in this study appear to support the conclusion of a post-1976 disposal. This agrees with the particle size data from the 1976 disposal area collections (Sweeney, 1978).

- <u>Grain-Size Distribution</u>

The spatial distribution of the sand, silt, and clay fractions of the sediment samples from disposal area D2 are mapped in Figures 3-10, 3-11, and 3-12, respectively. These figures show a consistent pattern of high sand and low silt-clay content in the northwestern corner of the area. The sand component steadily decreases in an eastward direction through disposal area D2.

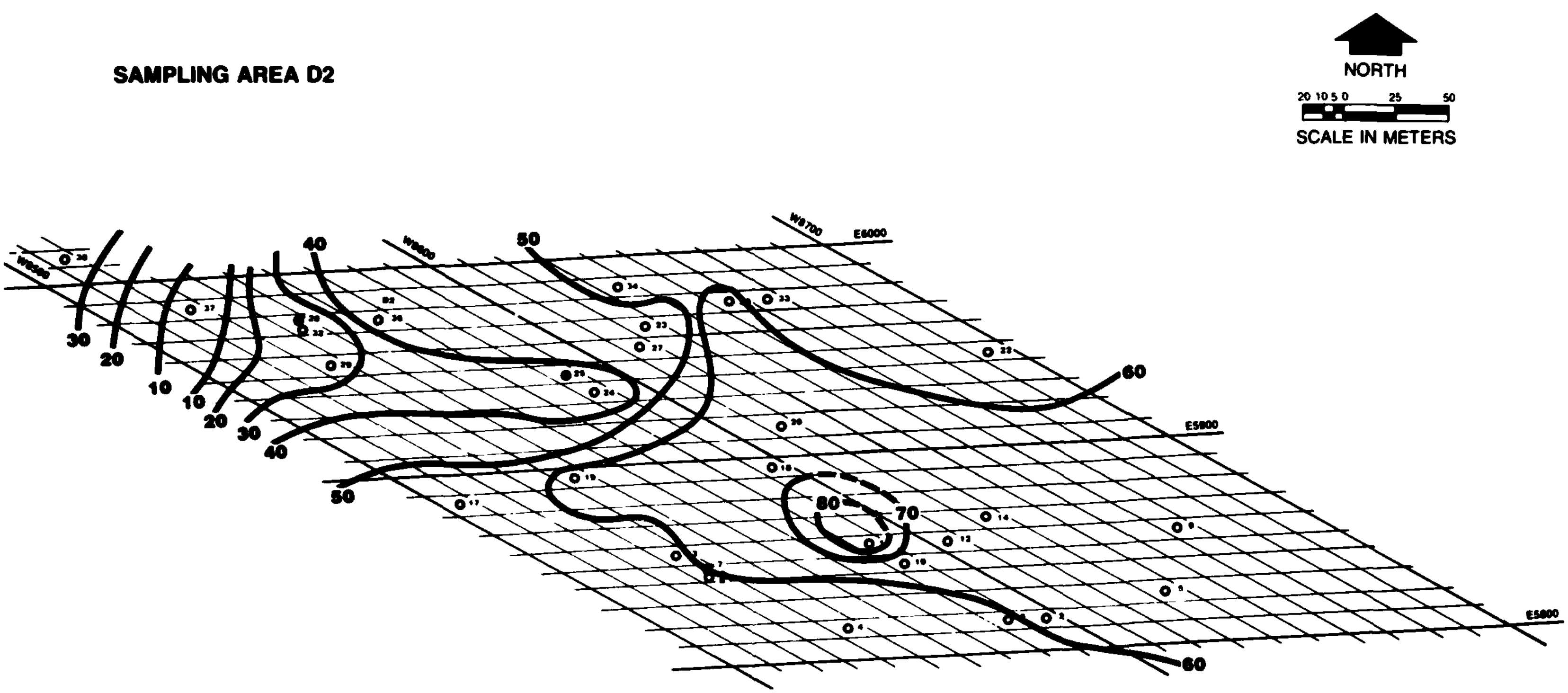


NOTE: THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE, IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2)

o[12]	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SAND IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)
•	INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-10
ISOPLETHS OF PERCENT SAND IN SEDIMENT — SAMPLING AREA D2

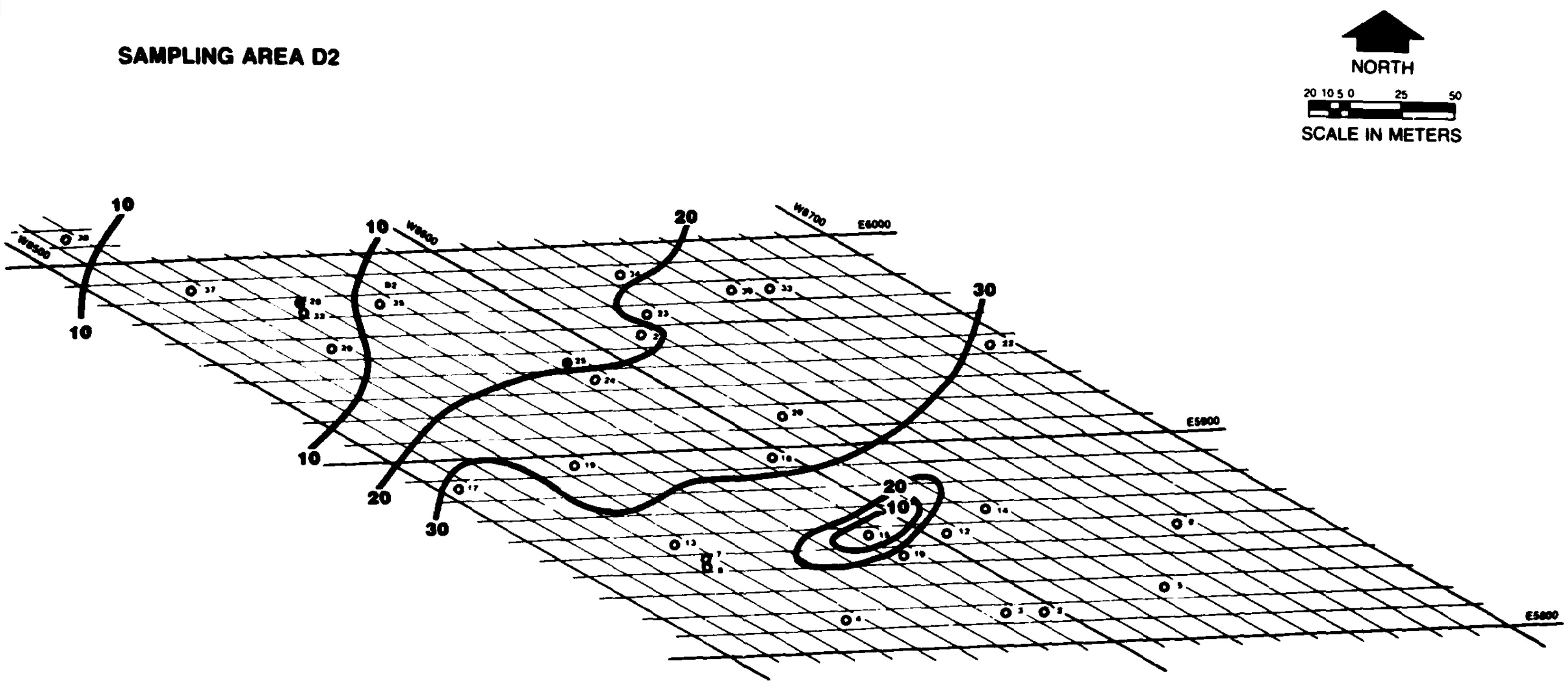


NOTE: THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE, IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2)

12	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SILT IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT) – BROKEN LINES REPRESENT EXTRAPOLATED VALUES
●	INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-11
ISOPLETHS OF PERCENT SILT IN SEDIMENT
— SAMPLING AREA D2



NOTE: THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE, IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2)

- LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
- ISOPLETH OF PERCENT CLAY IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)
- INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-12
ISOPLETHS OF PERCENT CLAY IN SEDIMENT — SAMPLING AREA D2

3.2.4 Disposal Area D8

- Grain-Size Characteristics

The sediment of disposal area D8 was sampled at 22 locations. A summary of the grain-size fractions found in random samples throughout this area is presented in Table 3-4. These samples exhibit a wide range of variability with respect to sediment grain size. The distribution presents a relatively continuous change from one extreme of the range to the other. This continuous variation of textural properties is shown graphically in the ternary diagram (Figure 3-13). The silt-clay ratios of the disposal area D8 samples fall within a narrow range, suggesting the separate origins of the sand and silt-clay fractions of the sediments. As noted for the disposal area D2 sediments, the silt and clay fractions represent the naturally occurring substrate, while the sand fraction may be derived from the disposed dredged material.

- Grain-Size Distribution

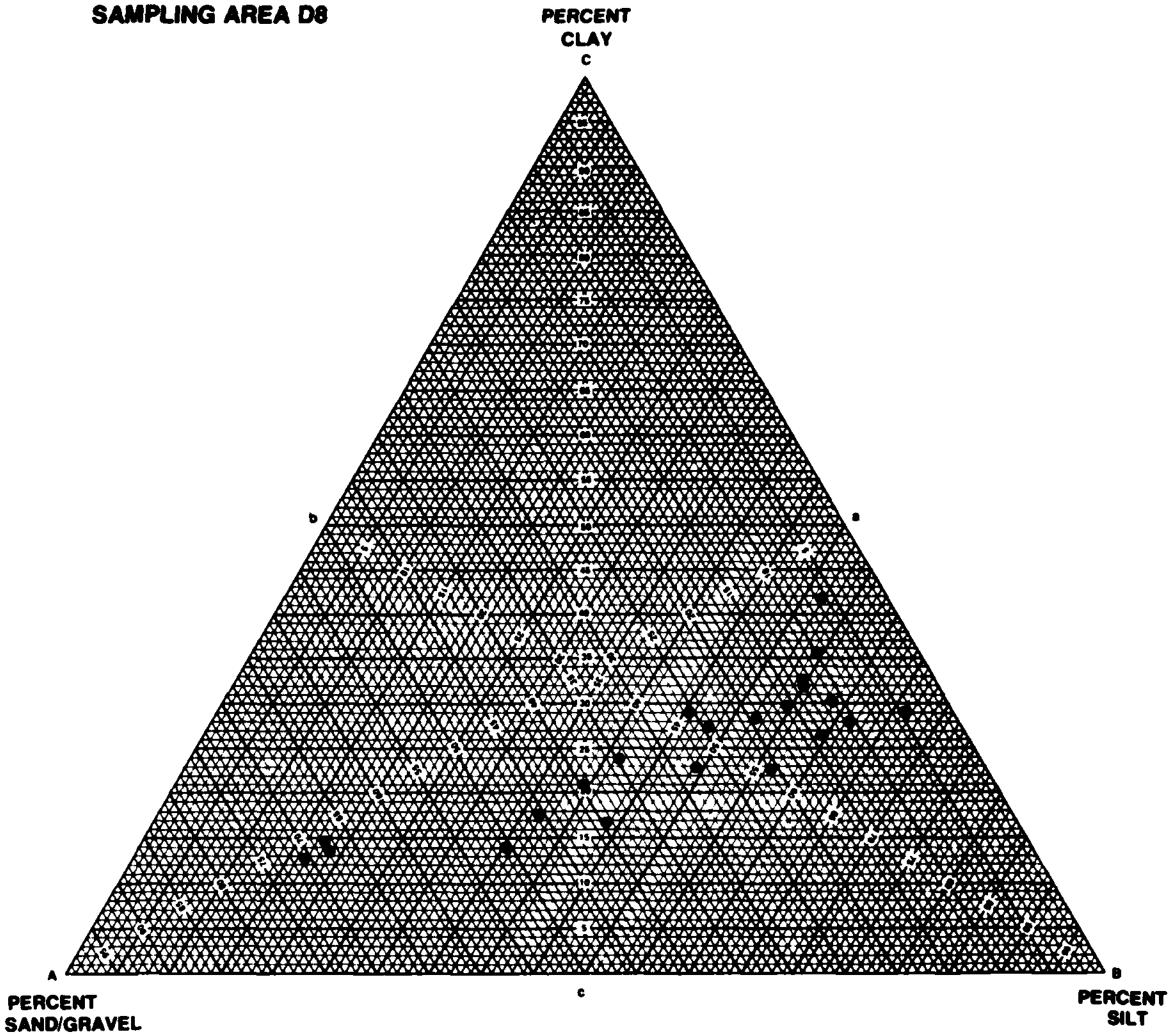
Figures 3-14, 3-15, 3-16, and 3-17 illustrate the geographic distribution of the gravel, sand, silt, and clay fractions, respectively, of the samples from disposal area D8. These plots show a high concentration of gravel in the northern and southern corners of the study area. The high gravel concentration in these corners was intermixed with sand, suggesting a common origin such as the deposition of dredged material.

Table 3-4

Grain-Size Distribution of Disposal Area D8

Mean ± Standard Deviation and Range of Sediment Samples

	Percent Sediment			
Sample No.	Gravel	Sand	Silt	Clay
D8-01	0.0	24.2	47.9	27.9
D8-03	0.0	20.1	56.7	23.2
D8-04	0.0	12.7	54.3	33.0
D8-05	36.8	31.0	18.2	14.0
D8-06	0.0	15.4	54.0	30.6
D8-07	0.6	9.6	54.4	35.4
D8-10	47.8	20.1	17.4	14.7
D8-11	0.8	10.3	61.1	27.8
D8-13	11.5	23.1	41.1	24.3
D8-14	21.5	6.5	49.0	23.0
D8-15	23.4	15.8	43.6	17.2
D8-16	0.4	13.6	59.8	26.2
D8-18	8.3	37.0	36.5	18.2
D8-20	0.0	4.6	66.1	29.3
D8-21	1.7	38.0	39.2	21.1
D8-23	40.6	9.8	35.1	14.5
D8-24	6.9	18.8	45.1	29.2
D8-25	0.9	12.1	54.6	32.4
D8-27	0.0	6.5	51.6	41.9
D8-29	0.0	10.8	58.8	30.4
D8-34	0.6	18.9	51.4	29.1
D8-38	54.0	16.1	16.5	13.4
All Samples Mean ± SD	11.6 ± 17.6	17.0 ± 9.2	46.0 ± 14.1	25.3 ± 7.7
(n)	22	22	22	22
Range	0.0 - 54.0	4.6 - 38.0	16.5 - 66.1	13.4 - 41.9

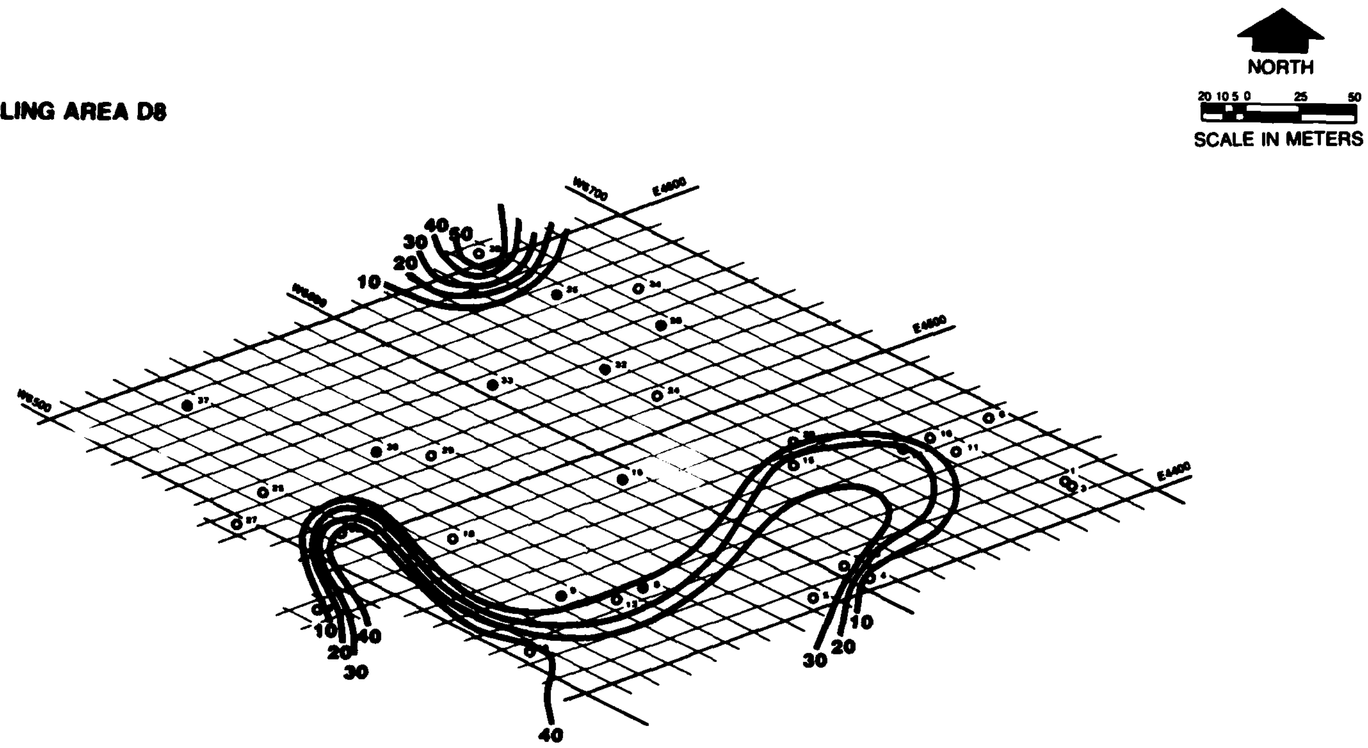


NOTE: EACH POINT ON THE DIAGRAM REPRESENTS THE PERCENT GRAIN-SIZE DISTRIBUTION OF A SINGLE SEDIMENT SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-13
TERNARY DIAGRAM OF SEDIMENT GRAIN-SIZE FRACTIONS — SAMPLING AREA D8

SAMPLING AREA D8



NOTE: THIS PLAN VIEW OF THE SAMPLING AREA
IS SHOWN AS A STRAIGHT LINE REPRESENTATION
OF THE TRUE, IN-FIELD, CURVED LINE PLOT
(SEE FIGURE 2-2)

LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION

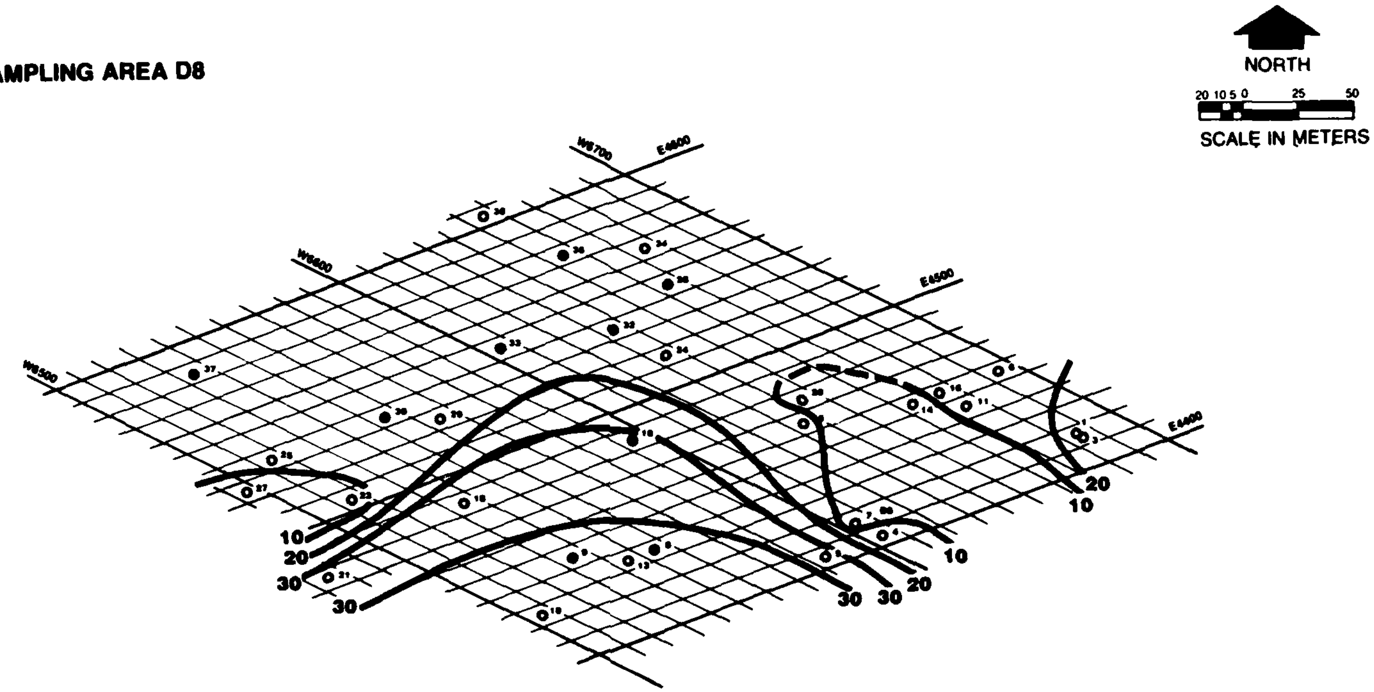
ISOPLETH OF PERCENT GRAVEL IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)

INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-14
ISOPLETHS OF PERCENT GRAVEL IN SEDIMENT — SAMPLING AREA D8

SAMPLING AREA D8



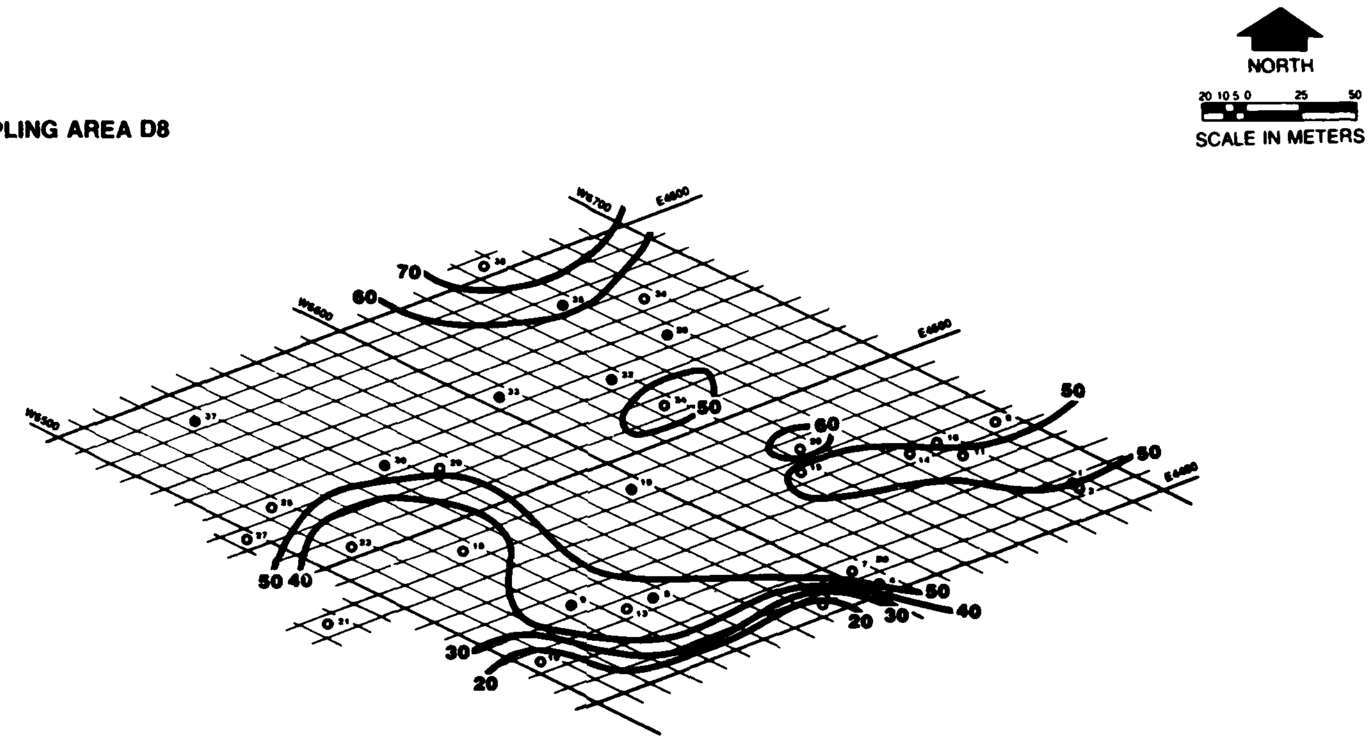
NOTE: THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE, IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2

○	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SAND IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT) – BROKEN LINES REPRESENT EXTRAPOLATED VALUES
●	INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-15
ISOPLETHS OF PERCENT SAND IN SEDIMENT – SAMPLING AREA D8

SAMPLING AREA D8



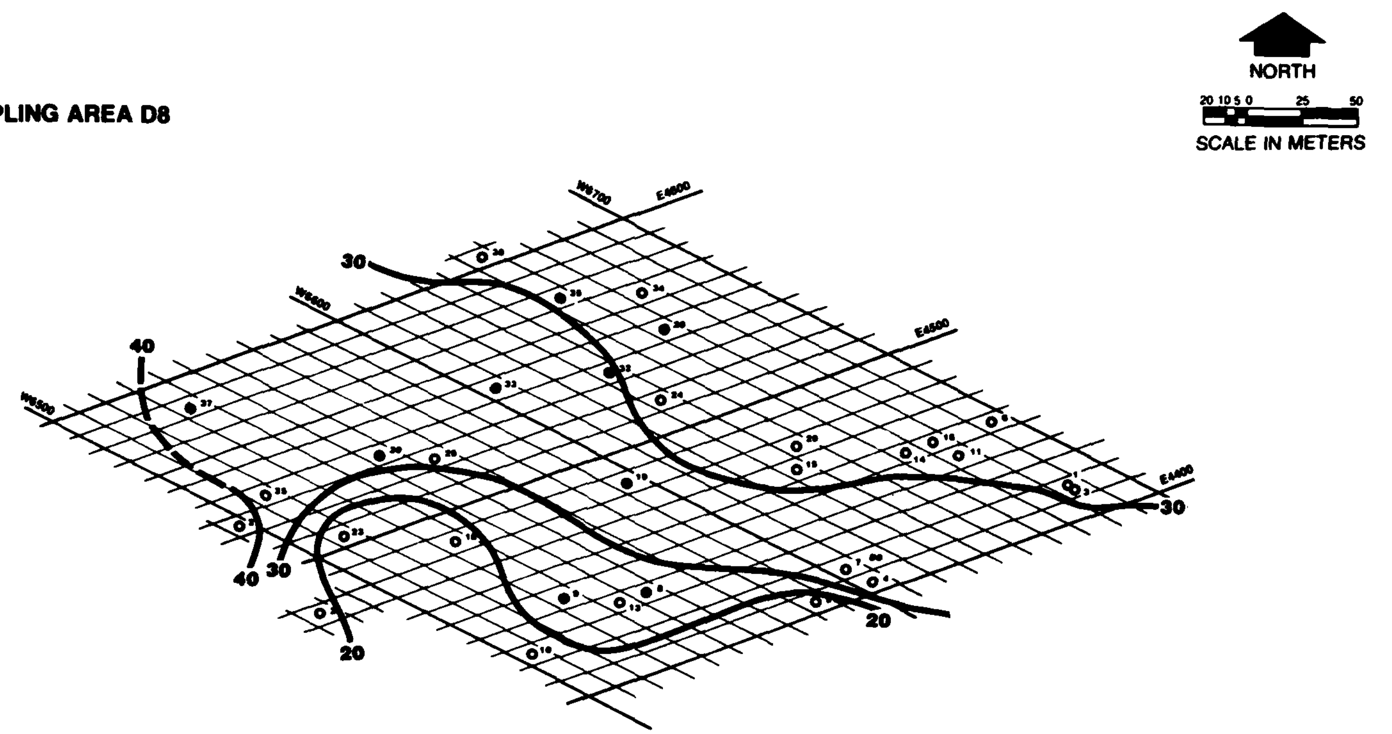
NOTE: THIS PLAN VIEW OF THE SAMPLING AREA
IS SHOWN AS A STRAIGHT LINE REPRESENTATION
OF THE TRUE, IN-FIELD, CURVED LINE PLOT
(SEE FIGURE 2-2)

° 16	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SILT IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)
•	INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-16
ISOPLETHS OF PERCENT SILT IN SEDIMENT — SAMPLING AREA D8

SAMPLING AREA D8



NOTE: THIS PLAN VIEW OF THE SAMPLING AREA
IS SHOWN AS A STRAIGHT LINE REPRESENTATION
OF THE TRUE, IN-FIELD, CURVED LINE PLOT
(SEE FIGURE 2-2)

LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION

ISOPLETH OF PERCENT CLAY IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT) — BROKEN LINES REPRESENT EXTRAPOLATED VALUES

INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-17
ISOPLETHS OF PERCENT CLAY IN SEDIMENT — SAMPLING AREA D8

3.2.5 Disposal Area ND

- Grain-Size Characteristics

Only seventeen collected sediment samples were adequate for analysis from study area ND. Most sample grabs from disposal area ND were shale and rock, and therefore not valid for comparison to other study sites. Table 3-5 summarizes the range of grain size properties determined for these samples. The grain size composition of each sample is illustrated in a ternary diagram (Figure 3-18). The silt-clay ratio is very narrow, while the sand-clay and sand-silt ratios vary markedly. The variations are generally continuous, with only two samples (ND-11 containing 93.62% sand and gravel, and ND-29 with 88.65% sand and gravel) significantly different from the rest. As seen in the other two disposal areas, the silt and clay fractions appear to be characteristic of the natural substrate, while rock, sand, and gravel portions probably resulted from disposal of dredged material.

- Grain-Size Distribution

The spatial distribution of the sand, silt, and clay fractions of the study area ND samples is shown in Figures 3-19, 3-20, and 3-21, respectively. The gravel fraction is not shown because it does not exhibit enough variation to display with meaningful contours. The textural distribution of sediments within study area ND includes a large central area with high sand content. This tapers in a regular pattern to a silty-clay area similar in texture to the sediment samples from the two control areas.

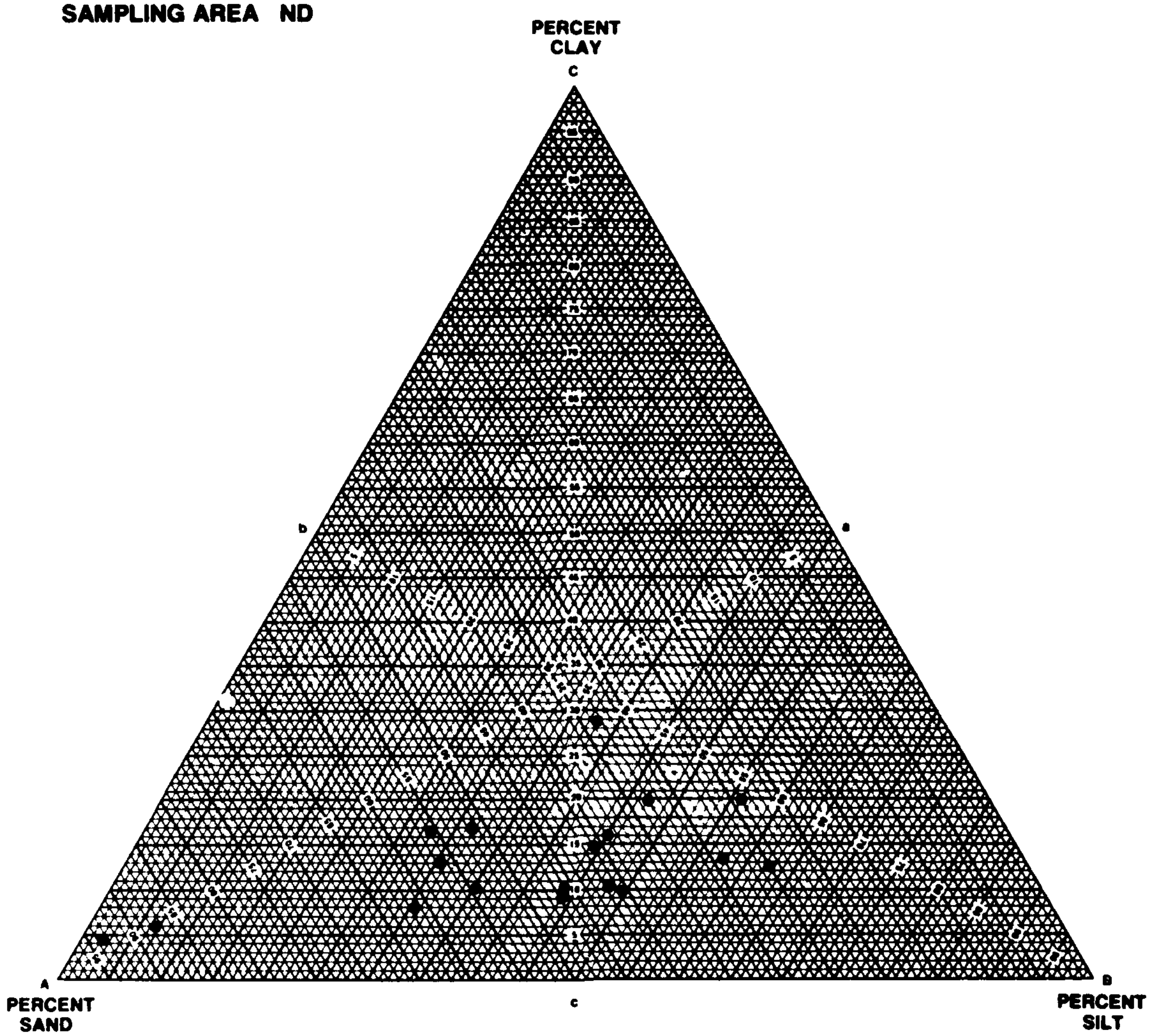
Table 3-5

Grain Size-Distribution of Disposal Area ND

Mean ± Standard Deviation and Range of Sediment Samples

	Percent Sediment			
Sample No.	Gravel	Sand	Silt	Clay
ND-01	0.0	54.3	35.1	10.6
ND-07	0.0	29.4	57.6	13.0
ND-11	3.6	90.0	2.0	4.4
ND-16	1.7	40.1	48.8	9.4
ND-17	0.2	33.0	46.9	19.9
ND-20	17.1	16.2	37.7	29.0
ND-22	6.8	32.0	45.0	16.2
ND-24	0.7	45.6	44.1	9.6
ND-25	0.2	55.7	27.9	16.2
ND-26	0.3	24.7	62.6	12.4
ND-29	0.9	86.8	6.5	5.8
ND-30	0.6	40.3	44.7	14.4
ND-31	0.3	45.9	43.7	10.1
ND-32	0.2	40.4	49.5	9.9
ND-34	0.1	61.6	30.4	7.9
ND-35	7.1	44.7	31.8	16.4
ND-37	4.9	19.2	56.1	19.8
All Samples Mean ± SD	2.6 ± 4.4	44.7 ± 20.6	39.4 ± 16.3	13.2 ± 6.0
(n)	17	17	17	17
Range	0.0 - 17.1	16.2 - 90.0	2.0 - 62.6	4.4 - 29.0

SAMPLING AREA ND

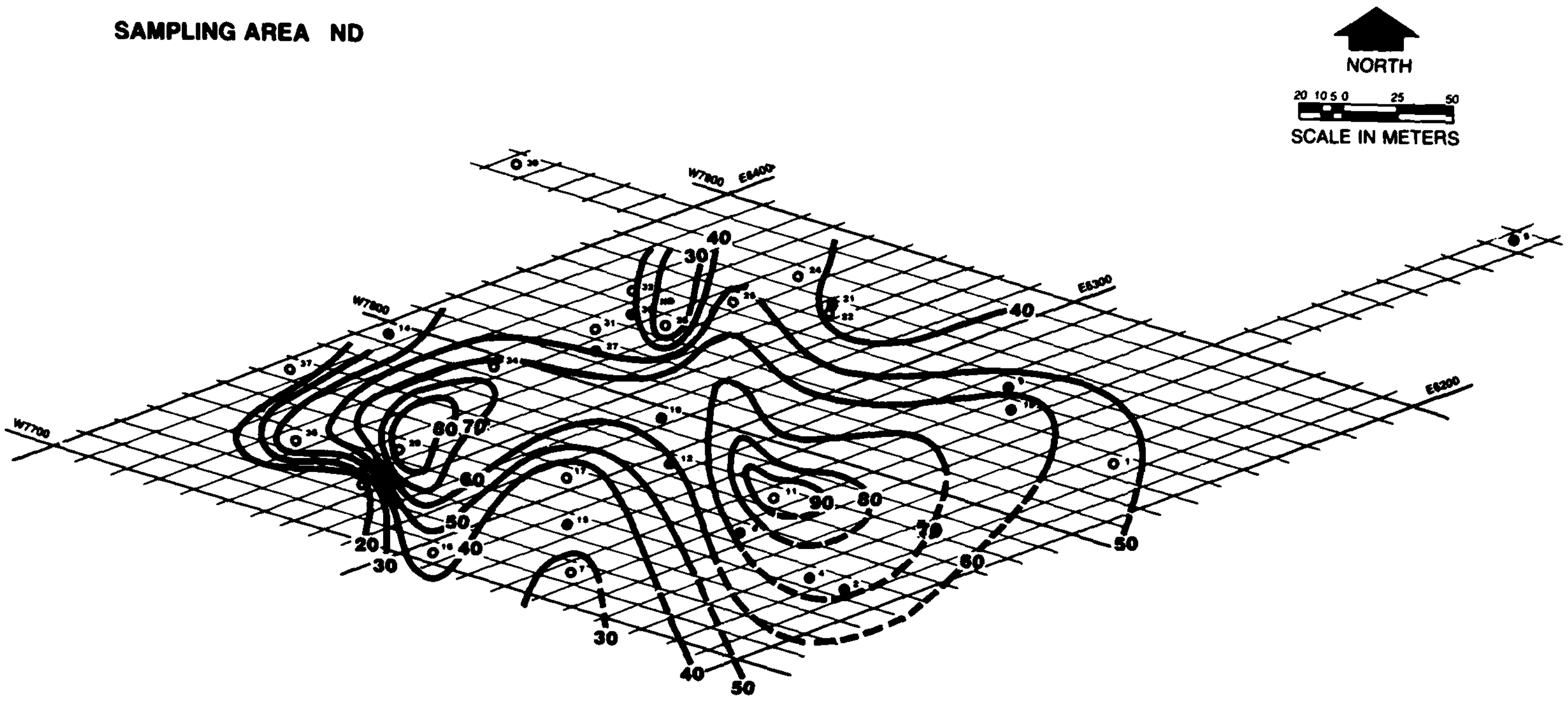


NOTE: EACH POINT ON THE DIAGRAM REPRESENTS THE PERCENT GRAIN-SIZE DISTRIBUTION OF A SINGLE SEDIMENT SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-18
TERNARY DIAGRAM OF SEDIMENT GRAIN-SIZE FRACTIONS — SAMPLING AREA ND

SAMPLING AREA ND



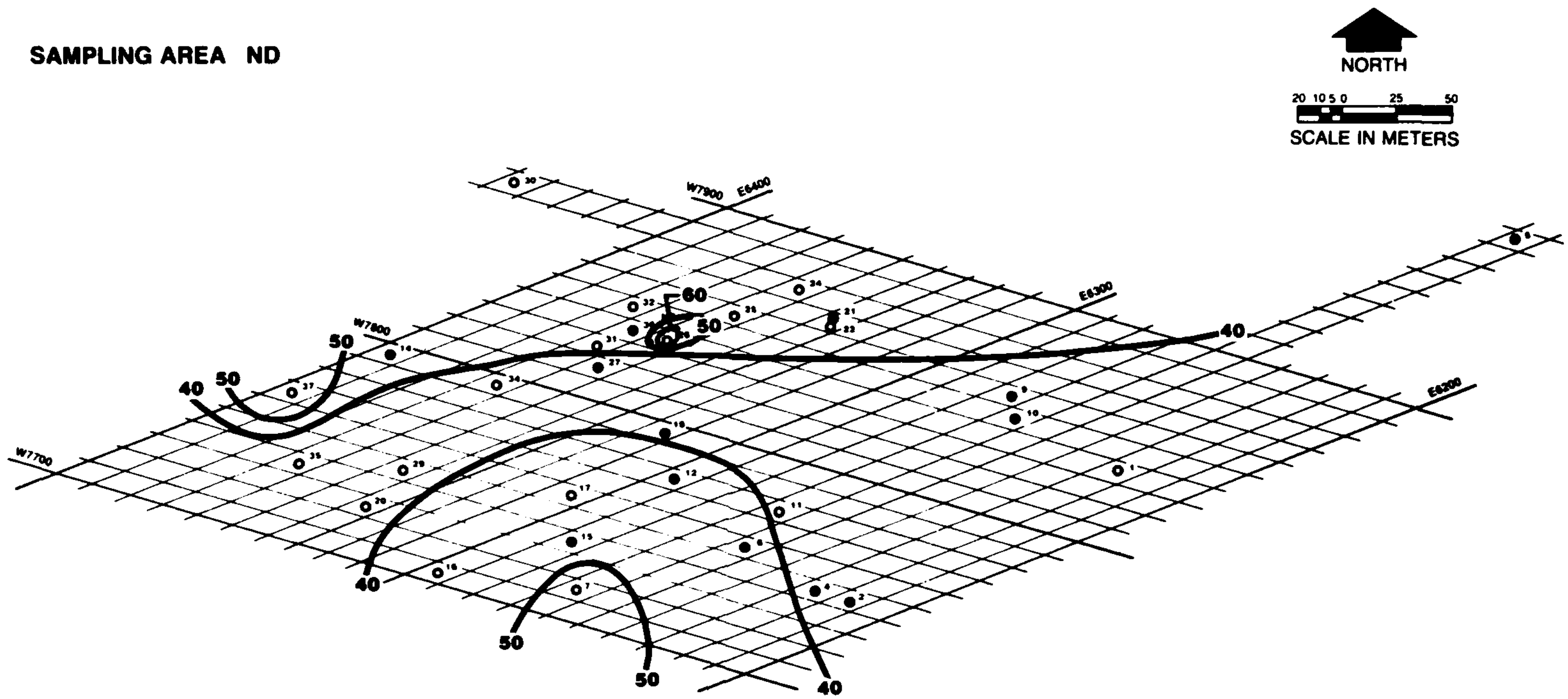
NOTE: THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE, IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2)

- LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
- 20 — ISOPLETH OF PERCENT SAND IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT) – BROKEN LINES REPRESENT EXTRAPOLATED VALUES
- INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-19
ISOPLETHS OF PERCENT SAND IN SEDIMENT — SAMPLING AREA ND

SAMPLING AREA ND

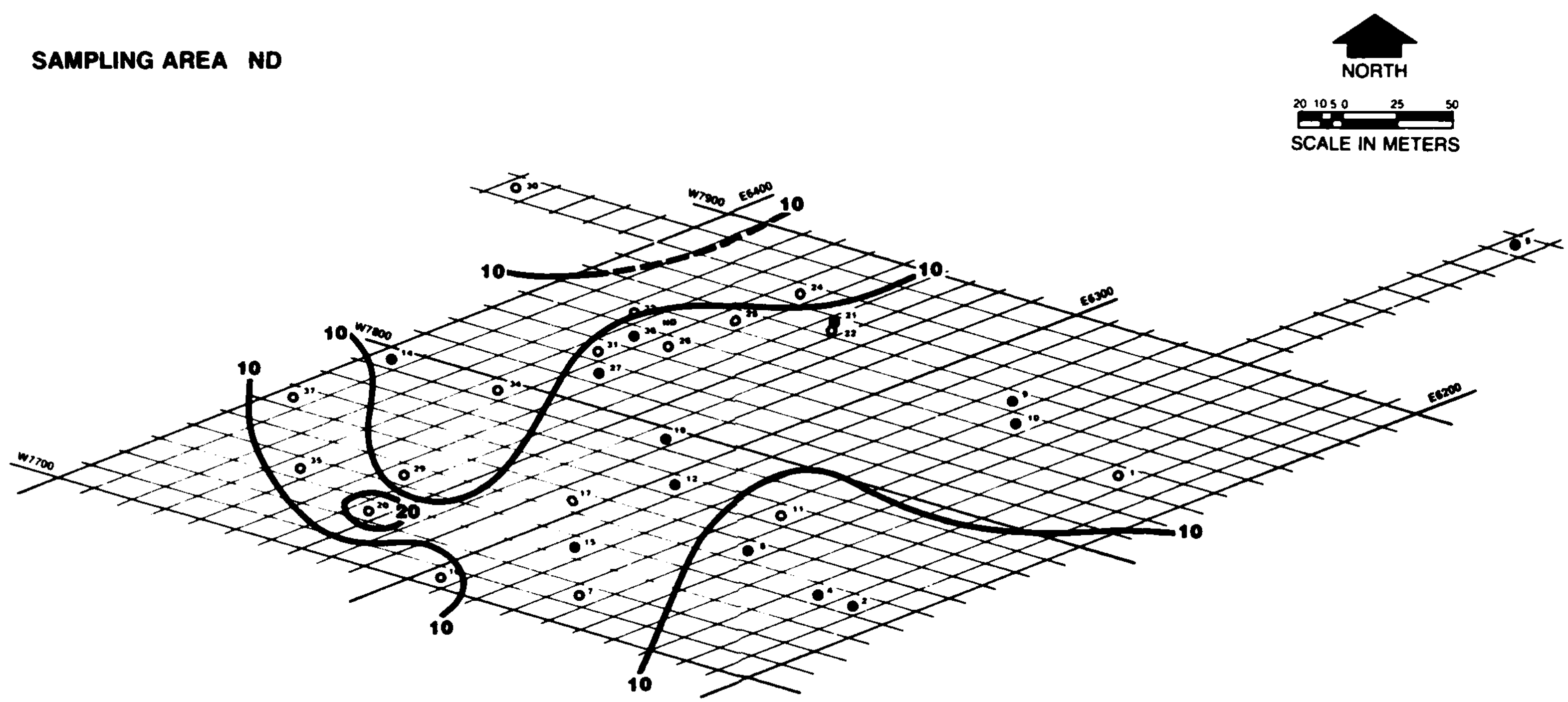


NOTE: THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE, IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2)

o 11	LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
20	ISOPLETH OF PERCENT SILT IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT)
●	INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-20
ISOPLETHS OF PERCENT SILT IN SEDIMENT
— SAMPLING AREA ND



NOTE. THIS PLAN VIEW OF THE SAMPLING AREA IS SHOWN AS A STRAIGHT LINE REPRESENTATION OF THE TRUE, IN-FIELD, CURVED LINE PLOT (SEE FIGURE 2-2)

- LOCATION OF SAMPLING STATION AND NUMERICAL DESIGNATION
- ISOPLETH OF PERCENT CLAY IN SEDIMENT SAMPLES (INTERVALS OF 10 PERCENT) — BROKEN LINES REPRESENT EXTRAPOLATED VALUES
- INCOMPLETE OR INADEQUATE SAMPLE

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-21
ISOPLETHS OF PERCENT CLAY IN SEDIMENT — SAMPLING AREA ND

3.3 BENTHIC MACROFAUNA

3.3.1 Abundance and Composition

A total of 128 upper and 106 lower horizon benthic macroinvertebrate samples were collected during the August 1979 field sampling. The taxa list and count data for both upper and lower core horizons are presented in Appendix B. A generally heterogeneous bottom community was found with many taxa showing high spatial variability throughout the study area.

The mean number of organisms per square meter (as numerically presented by Sweeney (1978)) for each of the sample stations is presented in Table 3-6 (upper strata) and Table 3-7 (lower strata). Unless otherwise noted, all further discussions on the macrofauna will deal with the upper strata (upper 10 cm) samples.

The mean density of total organisms per site was lowest in disposal areas ND and D8, intermediate in disposal area D2, and highest in control areas C1 and C3 (Figure 3-22). The mean number of taxa per site and mean diversity per site showed similar patterns (Figure 3-23 and 3-24). Analysis of variance failed to show any significant difference ($P>0.06$) between the control and test area in the number of organisms per site. However, an analysis of variance did show a significantly higher ($p<0.05$) number of taxa per site in the control area as compared to the test area.

Table 3-6

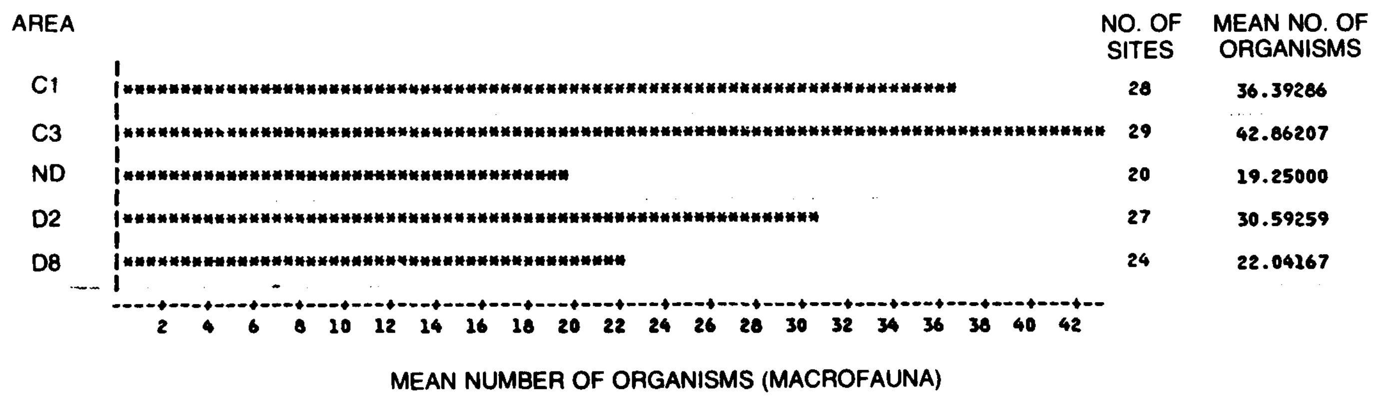
Macrofauna-Upper Strata	C1	C3	ND	D2	D8	Total Control	Total Disposal
			Organisms/Meter^2 *				
Polychaeta							
Manyunkia speciosa	0	18	18	2	5	18	25
Oligochaeta							
Aulodrilus americanus	101	125	26	77	23	226	126
A. limnobius	8	8	-	4	11	16	15
A. piqueti	16	22	-	4	14	38	18
A. pluriseta	361	661	53	276	20	1,022	349
Limnodrilus sp.	2	22	24	16	9	24	49
L. cervix	-	12	12	2	2	12	16
L. claparedianus	4	-	-	-	-	4	-
L. hoffmeisteri	55	86	82	132	97	141	311
L. maumeensis	2	12	9	12	16	14	37
L. profundicola	2	4	-	2	2	6	4
Peloscolex sp.	2	-	-	4	9	2	13
P. ferox	14	2	147	10	68	16	225
P. multisetosus	2	10	26	30	5	12	61
Potamothrix moldaviensis	6	-	-	-	2	6	2
P. vejdovskyi	18	31	62	45	36	49	143
Imm.Tubificidae w/hair setae	189	278	85	172	59	467	316
Imm.Tubificidae w/o hair setae	588	594	262	566	450	1,182	1,278
Dero digitata	-	-	3	-	-	-	3
Stylaria sp.	18	43	29	49	-	61	78
Nais sp.	6	2	-	4	-	8	4
Undetermined Naididae	12	16	3	20	29	28	52
Paranais frici	-	-	-	2	-	-	2
Hirundinea							
Glossiphona sp.	-	2	-	-	-	2	-
Helobdella stagnalis	59	43	24	28	27	102	79
Crustacea							
Gammarus sp.	4	-	-	-	2	4	2
Asellus sp.	140	208	47	107	138	348	292
Gastropoda							
Amnicola sp.	2	-	6	8	2	2	16
Valvata sp.	-	-	-	4	5	-	9
Bithynia tentaculata	-	2	15	2	5	2	22
Pelecypoda							
Musculium sp.	105	35	18	8	-	140	26
Pisidium sp.	28	39	-	16	11	67	27
Sphaerium sp.	205	192	38	53	32	397	123
Insecta							
Chironomus sp.	49	12	12	14	27	61	53
Procladius sp.	26	33	18	14	41	59	73
Dicrotendipes sp.	-	-	-	-	-	-	-
Glyptotendipes sp.	2	-	-	-	-	2	-
Corynoneura sp.	-	-	-	2	-	-	2
Tanytarsus sp.	-	2	3	-	-	2	3
Undetermined Chironomidae	57	51	9	45	32	108	86
Nematoda	30	22	6	6	23	52	35
TOTAL ORGANISMS	2,115	2,587	1,037	1,736	1,202	4,702	3,975

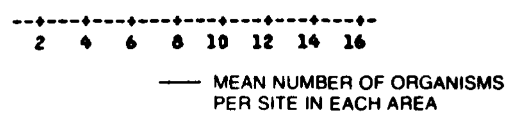
* Based on calculation of organisms/m^2 derived from actual surface sample area of 170 cm^2.

Table 3-7

Macrofauna-Lower Strata	AREAS C1	C3	ND	D2	D8	Total Control	Total Disposal
	Organisms/Meter^2 *						
Polychaeta							
Manyunkia speciosa	-	-	-	-	-	-	-
Oligochaeta							
Aulodrilus americanus	18	16	5	-	8	34	13
A. limnobius	-	-	-	-	-	-	-
A. piqueti	6	-	-	-	-	6	-
A. pluriseta	26	45	15	13	4	71	32
Limnodrilus sp.	2	4	-	-	-	6	-
L. cervix	-	-	-	-	-	-	-
L. claparedianus	-	-	-	-	-	-	-
L. hoffmeisteri	41	24	15	13	31	65	59
L. maumeensis	-	6	-	-	-	6	-
L. profundicola	-	-	-	-	-	-	-
Peloscolex sp.	2	-	-	5	-	2	5
P. ferox	6	-	20	-	12	6	32
P. multisetosus	8	4	10	10	8	12	28
Potamothrix moldaviensis	-	-	-	-	-	-	-
P. vejdovskyi	-	-	-	-	4	-	4
Imm.Tubificidae w/hair setae	16	14	10	15	8	30	33
Imm.Tubificidae w/o hair setae	193	76	20	49	102	269	171
Dero digitata	-	-	-	-	-	-	-
Stylaria sp.	-	-	-	-	-	-	-
Nais sp.	-	-	-	-	-	-	-
Undertermined Naididae	-	2	-	3	-	2	3
Paranais frici	-	-	-	-	-	-	-
Lumbricolidae	-	-	-	-	4	-	4
Chaetogaster sp.	-	2	-	-	-	2	-
Hirundinea							
Glossiphona sp.	-	6	-	-	-	6	-
Helobdella stagnalis	14	2	-	-	-	16	-
Crustacea							
Gammarus sp.	-	-	-	-	-	-	-
Asellus sp.	8	6	-	-	-	14	-
Gastropoda							
Amnicola sp.	-	2	-	-	-	2	-
Valvata sp.	-	-	-	-	-	-	-
Bithynia tentaculata	-	18	-	-	-	18	-
Pelecypoda							
Musculium sp.	34	-	-	-	-	34	-
Pisidium sp.	16	31	34	-	-	47	34
Sphaerium sp.	101	73	25	-	-	174	25
Insecta							
Chironomus sp.	10	-	-	-	-	10	-
Procladius sp.	16	12	15	3	4	28	22
Dicrotendipes sp.	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-
Corynoneura sp.	-	-	-	-	-	-	-
Tanytarsus sp.	30	-	20	3	4	30	27
Undetermined Chironomidae	2	-	-	-	-	2	-
Nematoda	28	8	-	8	4	36	12
TOTAL ORGANISMS	577	351	189	122	193	928	504

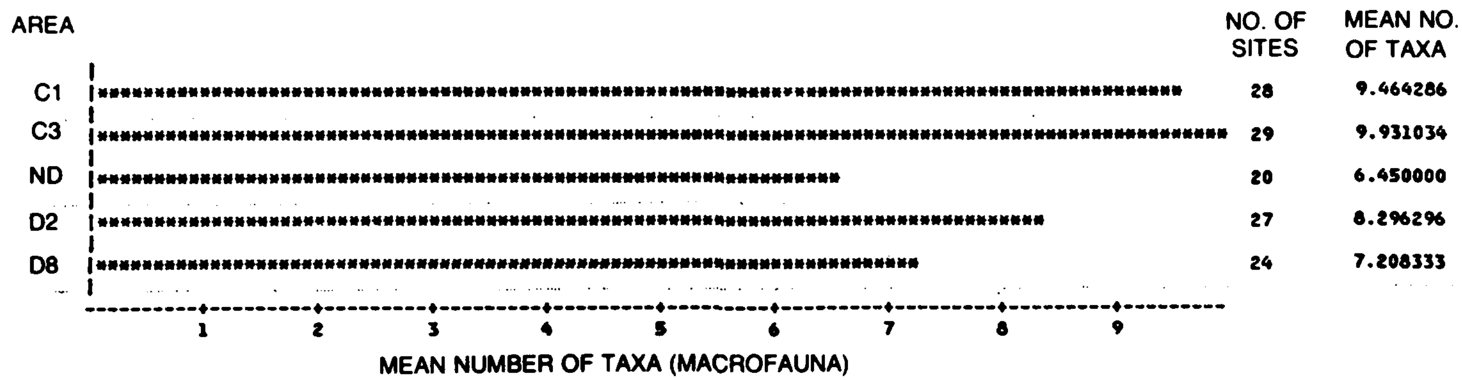
* Based on calculation of organisms/m^2 derived from actual surface sample area of 170 cm^2.

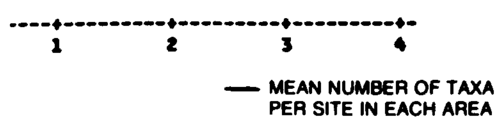




LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

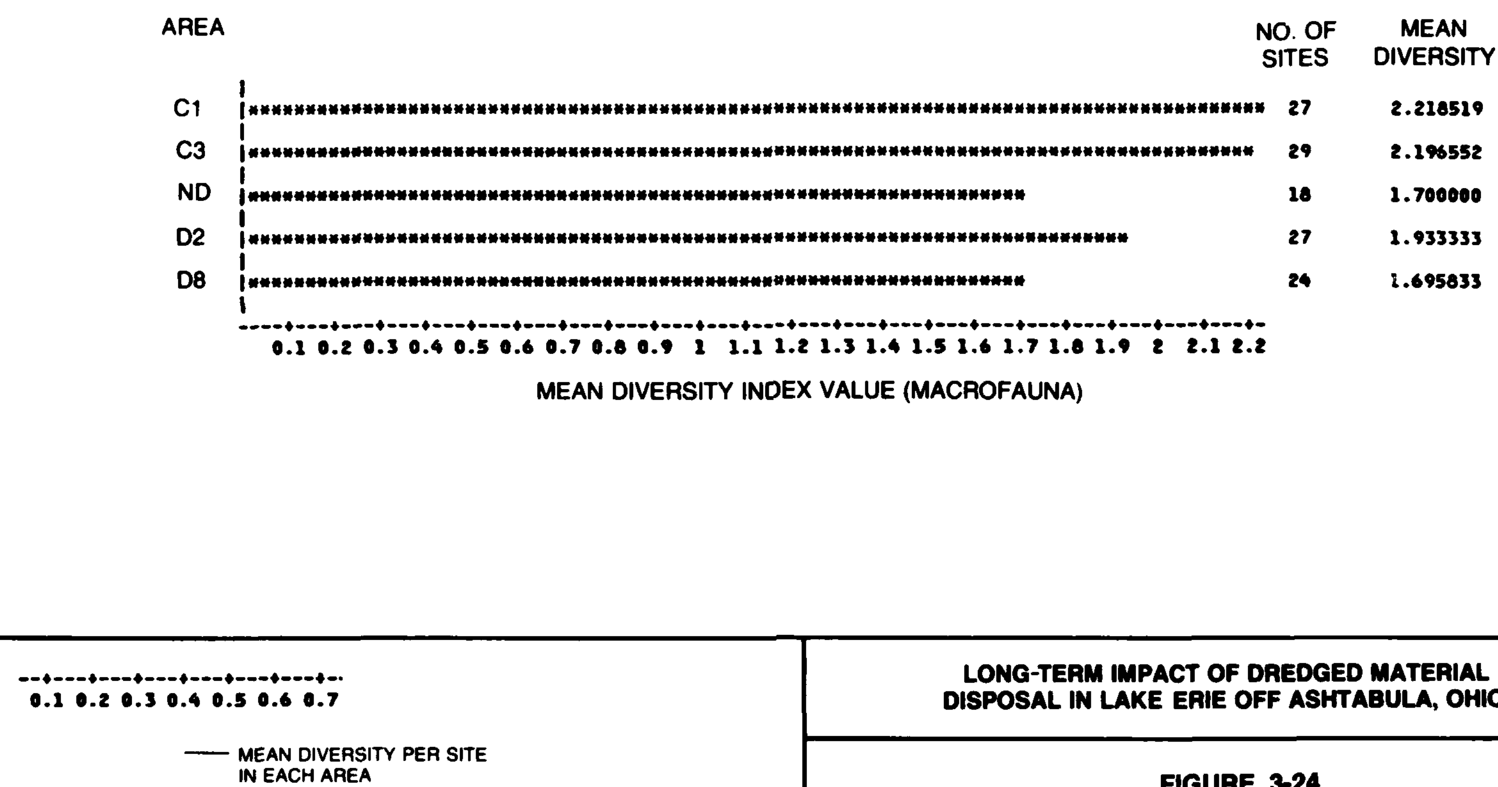
FIGURE 3-22
BAR CHART OF MEAN NUMBER OF MACROFAUNA PER SITE IN EACH AREA





LONG-TERM IMPACT OF DREDGED MATERIAL
DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-23
BAR CHART OF MEAN NUMBER OF TAXA (MACROFAUNA) PER SITE IN EACH AREA



LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-24
BAR CHART OF MEAN DIVERSITY (MACROFAUNA) PER SITE IN EACH AREA

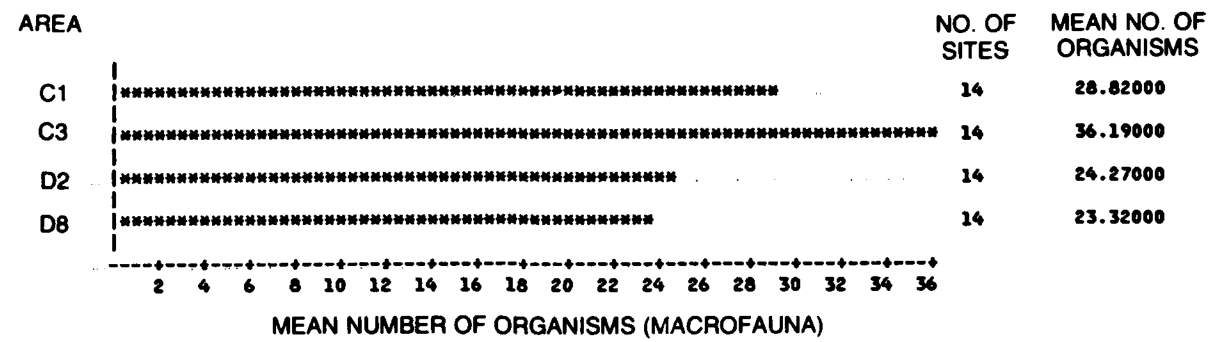
The sediment balanced data set showed greater similarity among the areas than the whole data set (Figures 3-25, 3-26, and 3-27); however, density, number of taxa, and diversity were still lower in the test areas. Analysis of variance showed no significant differences between the control and test areas for the number of organisms per site or for the number of taxa per site. Diversity values cannot be statistically analyzed (Green, 1979).

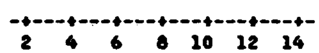
A block chart representing the mean number of organisms per site in each area for the major taxomonic groups is presented in Figure 3-28. Pelecypods, crustaceans (predominantly isopods), and chironomids followed oligochaetes in order of decreasing abundance in each area. All the major taxonomic groups were found in greater abundance in the control areas with the exception of the gastropods.

A block chart of the balanced data set with similar sediment characteristics showed a similar relationship (Figure 3-29). Oligochaetes remained the dominant component of this community. There appeared to be a slight reduction in the faunal variation between test and control areas.

Oligochaeta strongly dominated the bottom fauna of both control and disposal areas. Eighteen species, dominated by members of the Tubificidae, *Aulodrilus* sp., and *Limnodrilus* sp., were identified, and accounted for 67 to 82 percent of all organisms enumerated. *A. pluriseta*, *A. americanus*, and *L. hoffmeisteri* were most abundant.

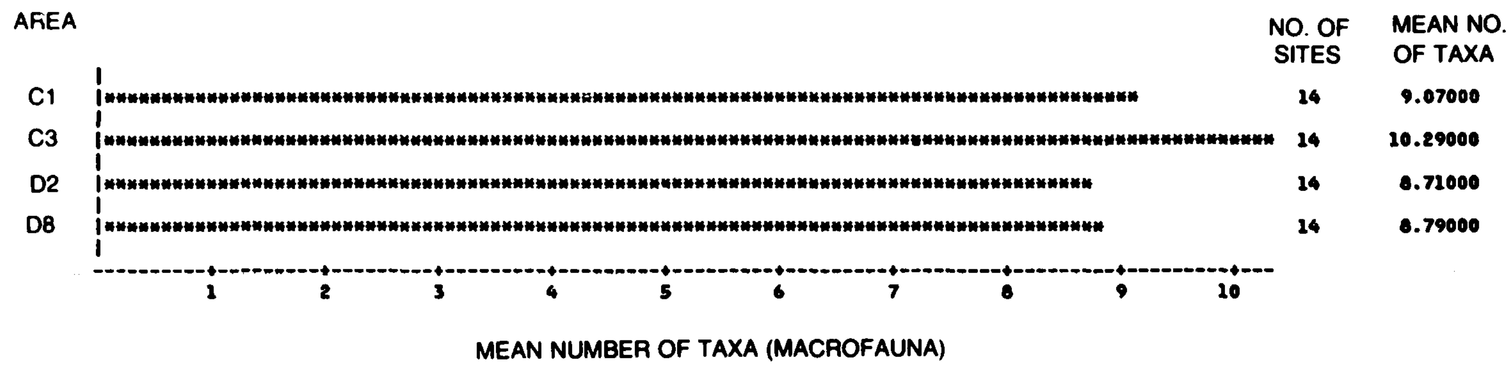
All pelecypods collected belonged to the family Sphaeriidae (pea clams), while the crustacea consisted almost entirely of the isopod *Asellus* sp. The chironomids were dominated by *Chironomus* sp. and *Procladius* sp. and contributed only a small percentage to the macrofaunal community.





LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-25
BAR CHART OF MEAN NUMBER OF MACROFAUNA PER SITE IN EACH AREA, BALANCED DATA SET WITH SIMILAR SEDIMENT CHARACTERISTICS

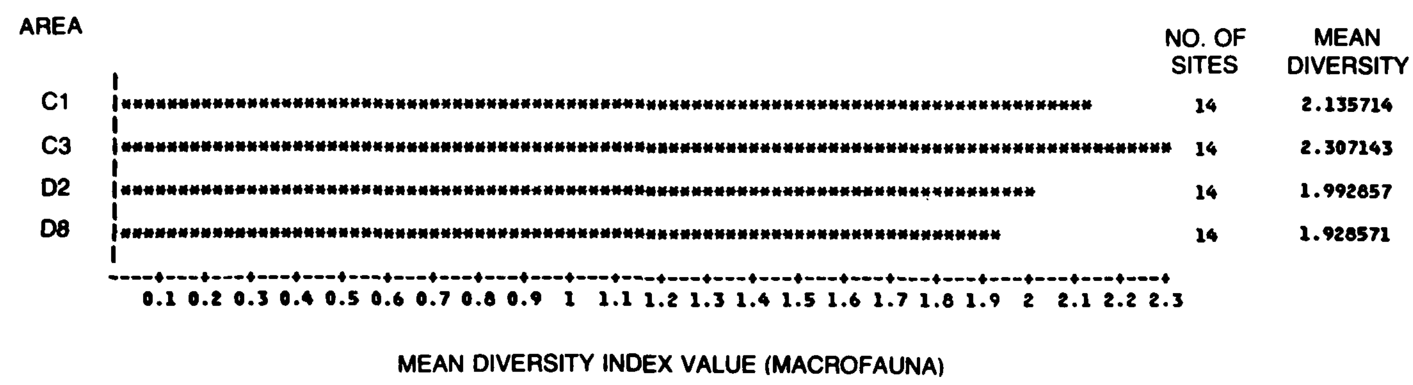


1 2 3 4

— MEAN NUMBER OF TAXA PER SITE IN EACH AREA

LONG TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-26
BAR CHART OF MEAN NUMBER OF TAXA (MACROFAUNA) PER SITE IN EACH AREA, BALANCED DATA SET WITH SIMILAR SEDIMENT CHARACTERISTICS

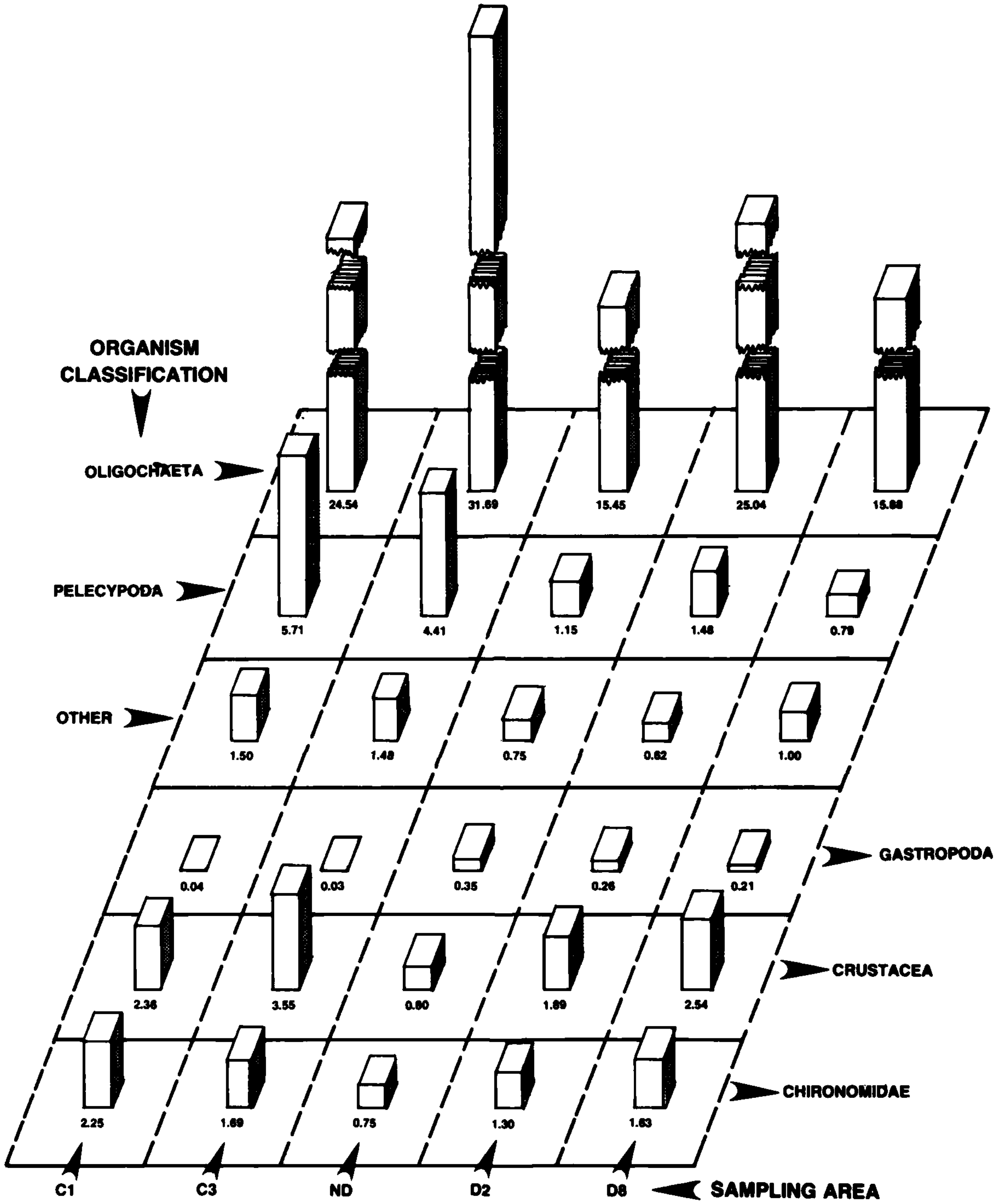


0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

— MEAN DIVERSITY PER SITE IN EACH AREA

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

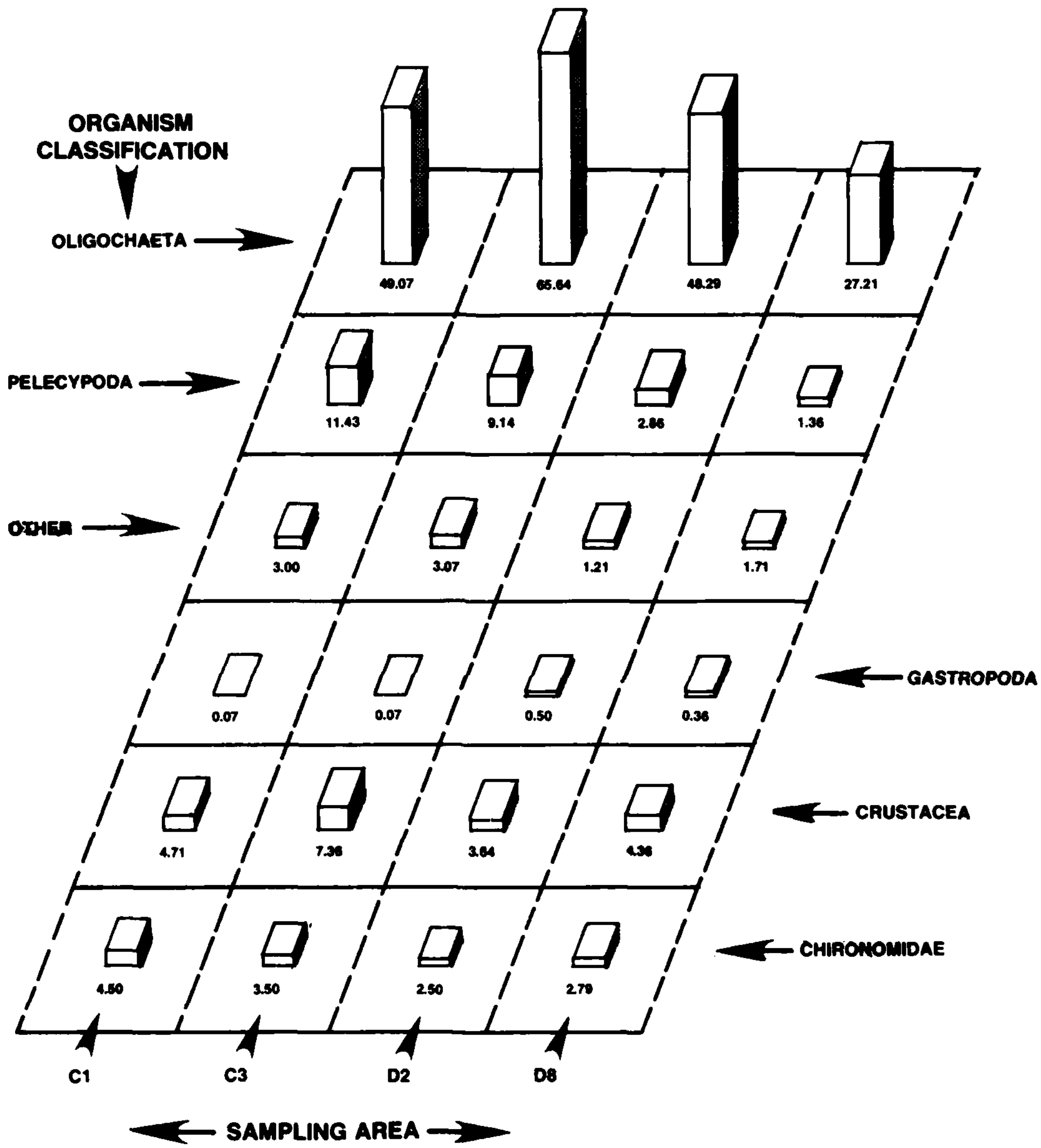
FIGURE 3-27
BAR CHART OF MEAN DIVERSITY (MACROFAUNA) PER SITE IN EACH AREA, BALANCED DATA SET WITH SIMILAR SEDIMENT CHARACTERISTICS



5.00 — MEAN NUMBER OF ORGANISMS PER SITE (REPRESENTED BY A BOX-CORE SAMPLE OF 170 CM²)

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-28
BLOCK DIAGRAM OF MACROFAUNAL GROUPS — WHOLE DATA SET



5.00 — MEAN NUMBER OF ORGANISMS PER SITE (REPRESENTED BY A BOX-CORE SAMPLE OF 170 CM²), SUBSETTED FOR SIMILAR SEDIMENTS

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-29
BLOCK DIAGRAM OF MACROFAUNAL GROUPS– BALANCED FOR SIMILAR SEDIMENTS

The density of organisms was substantially reduced in all lower horizon samples as compared to the upper horizon. Control area abundance remained greater than that of disposal areas. In addition, taxa diversity indices for the lower horizon areas were markedly less than the upper strata values. Within the lower horizon, the mean diversity index per site in the control areas was much greater than that of the disposal areas.

Oligochaetes dominated the lower horizons of both control and disposal areas. Twelve species were identified, of which two, *Lumbriculus* sp. and *Chaetogaster* sp., were found only in the lower strata. *Aulodrilus limnobius*, *Limnodrilus cervix*, *L. calaparedianus*, *L. profundicola*, *Potamotrix moldaviensis*, *Dero digitata*, *Stylaria* sp., and *Paranais frici*, observed in the upper strata, were not present in the lower horizon. As noted also in the upper horizon samples, tubificids were most abundant among the oligochaetes, followed by *A. pluriseta* and *L. hoffmeisteri*.

The Pelecypoda were the only other abundant organisms in the lower horizon, particularly in the control areas. *Gammarus*, and the insects *Glyptotendipes* sp. and *Corynoneura* sp., were not observed at all in the lower strata. In addition, several organisms observed in the lower strata were found only in the control areas. This group included the oligochaetes *A. piqueti*, *L. maumeensis*, and *Chaetogaster* sp.; all Hirudinea, Crustacea, and Gastropoda; the pelecypod *Musculium* sp.; and the chironomid insects. The opposite was true only for the oligochaetes *Lumbriculus* sp. and *Potamothrix vejdovskyi*.

ANOVA's for the major taxonomic groups were conducted on both the whole data set and the balanced data set with similar sediment characteristics. Significant differences ($P<0.02$) between control and disposal areas were detected only among the Gastropoda and Pelecypoda. Gastropods were found predominantly in the disposal areas, while pelecypods were more abundant in the control areas. These relationships were found in both the whole data set and the subsetted data set. In addition, isopods were found in significantly greater numbers ($P<0.02$) in the control areas in the balanced data set for similar sediment characteristics, but not in the whole data set. None of the other major taxonomic groups showed significant differences between the control and disposal areas.

3.3.2 Sediment Association

Individual species density organized by site, as well as by association with sediment characteristics as a function of Shepard Class, is presented in Appendix C. The majority of organisms were broadly based across both the test and control areas. Included in this group are the isopod *Asellus* sp; the oligochaetes *Aulodrilus americanus*, *A. limnobius*, *A. pluriseta*, *Limnodrilus hoffmeisteri*, *L. maumeensis*, *L. profundicola*, *Peloscolex multisetosus*, *Potamothrix vejdovskyi*, and *Stylaria* sp., as well as tubificid and naidid species; the chironomids *Chironomus* sp.; *Procladius* sp. and *Tanytarsus* sp.; the polychaete *Manyunkia speciosa*; the leech, *Helobedella stagnalis*; and the Nematoda.

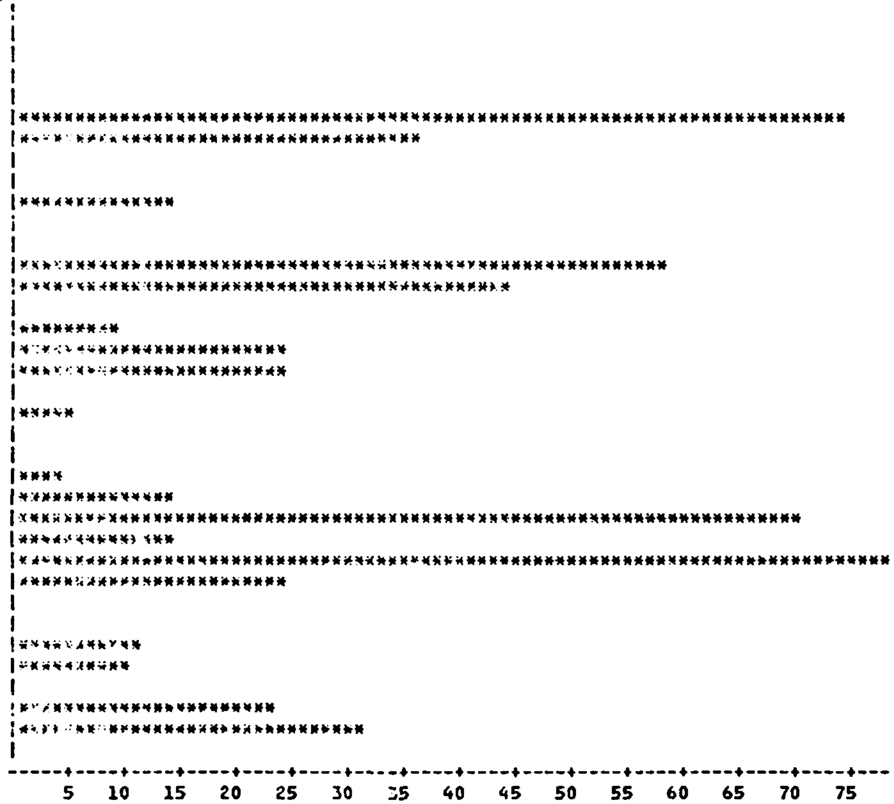
Among many other organisms, however, distinct control or disposal area associations were found. Control area sediments showed slightly more individual species association than disposal areas. The amphipod, *Gammarus* sp.; the leech, *Glossiphona* sp.;

the chironomid, Glyptotendipes sp.; and the oligochaete, L. claparedianus, were found exclusively in one or both of the control areas. Other species, including A. piqueti, L. cervix, Potamothrix moldaviensis, and all the pelecypods, were observed predominantly in the control areas.

Distinct species association with the disposal areas was also common. The insect, Corynoneura sp., the oligochaetes Dero digitata and Paranais frici, and the gastropod, Valvata sp., were present exclusively in the disposal areas. All remaining gastropod species, with the exception of four individuals, were found exclusively in the disposal zones. In addition, the density of all Peloscolex species was far greater in disposal than in control areas.

It should be noted that many of the above-mentioned organisms were found in low numbers, and their presence or absence may have resulted from random selection, as opposed to distinct area association.

As demonstrated by the association between higher densities and higher Shepard Class values, organism density was generally higher in the finer sediments throughout the test and control areas (Figure 3-30). The number of taxa per area showed a relationship similar to that of density, as noted by the association between the mean number of taxa and sediment characteristics (Figure 3-31). The largest number of taxa per site were generally present in Shepard Class 6 and 7 (high silt-clay), and markedly reduced in areas of low silt-clay.

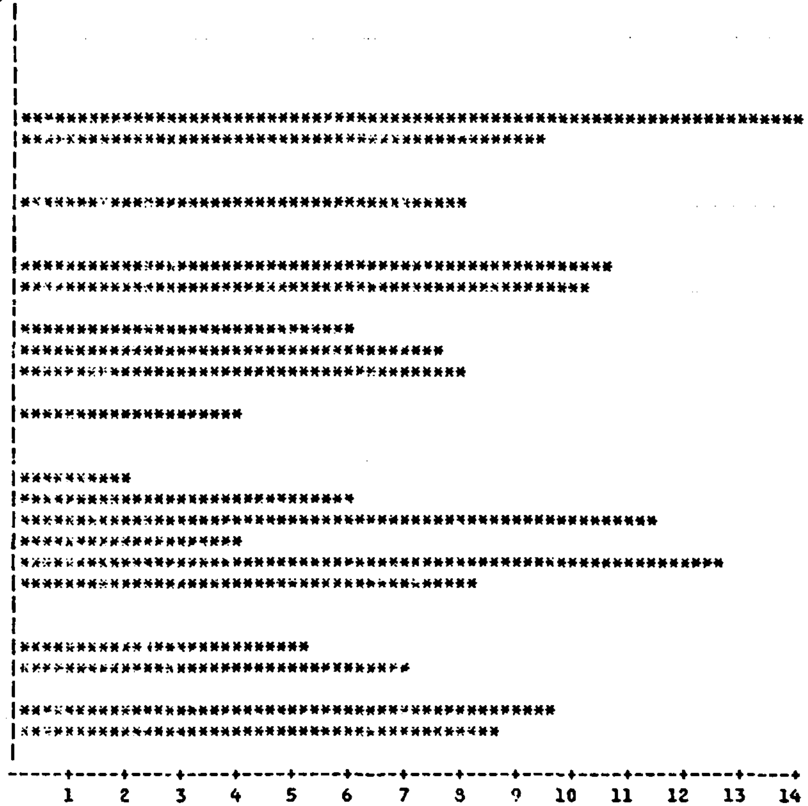


AREA	SHEPARD CLASS	NO. OF SITES	MEAN NO. OF ORGANISMS
C1	1	0	0.00000
	2	0	0.00000
	3	0	0.00000
	4	0	0.00000
	6	1	74.00000
	7	26	35.92308
C3	1	0	0.00000
	2	1	14.00000
	3	0	0.00000
	4	0	0.00000
	6	3	57.66667
	7	24	43.83333
ND	1	1	9.00000
	2	6	23.50000
	3	6	24.16667
	4	0	0.00000
	6	1	5.00000
	7	0	0.00000
D2	1	1	4.00000
	2	3	13.66667
	3	3	69.66667
	4	1	14.00000
	6	2	77.50000
	7	17	23.70508
D8	1	0	0.00000
	2	5	11.40000
	3	1	10.00000
	4	0	0.00000
	6	4	23.25000
	7	10	31.40000

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL II: LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-30
BAR CHART OF MEAN ABUNDANCE OF MACROFAUNA VERSUS SHEPARD CLASS

AREA	SHEPARD CLASS	NO. OF SITES	MEAN NO. OF TAXA
C1	1	0	0.00000
	2	0	0.00000
	3	0	0.00000
	4	0	0.00000
	6	1	14.00000
	7	26	9.38462
C3	1	0	0.00000
	2	1	8.00000
	3	0	0.00000
	4	0	0.00000
	6	3	10.66667
	7	24	10.20333
ND	1	1	6.00000
	2	6	7.50000
	3	6	8.00000
	4	0	0.00000
	6	1	4.00000
	7	0	0.00000
D2	1	1	2.00000
	2	3	6.00000
	3	3	11.33333
	4	1	4.00000
	6	2	12.50000
	7	17	8.29412
D8	1	0	0.00000
	2	5	5.20000
	3	1	7.00000
	4	0	0.00000
	6	4	9.50000
	7	10	8.50000



MEAN NUMBER OF TAXA (MACROFAUNA)

1 2 3 4 5 6

— MEAN NUMBER OF TAXA WITHIN EACH SHEPARD CLASS PER SITE GROUPED BY AREA

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-31
BAR CHART OF MEAN NUMBER OF TAXA (MACROFAUNA) VERSUS SHEPARD CLASS

A number of organisms were associated only with a particular Shepard Class sediment. The oligochates Dero digitata and Paranais frici, for example, were found only in Shepard Class 3, while Glossiphona, Glyptotendipes, and Corynoneura species were present only in Shepard Class 7. Nevertheless, no significant relationships were found between sediment type and specific organism density, either by correlation analysis or cluster analysis. High variation in organism density between individual stations within sites, and similarity of fauna across sites, obscured specific associations.

The mean diversity of taxa present in all sampling areas of both the upper and lower sample strata is given in Table 3-8. No within control or disposal area differences were found in taxa diversity. A moderate disposal area effect was observed, however, as a markedly lower diversity index calculated for each of the disposal areas, when compared to the control areas. In addition, the range of diversity indices was more narrow in control areas, indicating a more homogeneous environment and community. Site D2, as noted also for organism density, was most similar to the control areas in taxa diversity.

Taxa diversity indices for the lower horizons were markedly less than all upper strata values. Even so, the mean diversity index of the control site lower strata was much greater than that of the disposal areas. No differences were found within control or disposal sites.

Table 3-8

Macrofauna Taxa Diversity (H)

(mean ± 1 standard error)

Upper Horizon - A

	C1	C3	ND	D2	D8
mean ($\bar{x}$)	2.20 ± .08	2.22 ± .09	1.66 ± .16	1.88 ± .12	1.61 ± .13
(n)	29	30	20	29	26
range	1.25 - 2.95	0.90 - 2.91	0.0 - 2.55	0.5 - 3.06	0.0 - 2.78

Lower Horizon - B

	C1	C3	ND	D2	D8
mean ($\bar{x}$)	1.03 ± .14	.88 ± .13	.56 ± .20	.52 ± .12	.58 ± .15
(n)	29	23	10	18	13
range	0.0 - 2.62	0.0 - 2.25	0.0 - 1.71	0.0 - 1.76	0.0 - 2.02

3.4 BENTHIC MEIOFAUNA

3.4.1 Abundance and Composition

Subsampling from box core collections resulted in 224 upper and 25 lower horizon meiofauna samples. Taxa identification and enumeration at all sites for both upper and lower core horizons are presented in Appendix D. The number of lower strata samples was markedly reduced by the occurrence of coarse sediment fractions and substrate compaction. Since the Tardigrada, Hydracarina, and Gastropoda were rarely found in the meiofauna samples, they were included in the enumeration listing, but not in the statistical analyses. In addition, only "active" organisms were used in the analysis; thus, encysted organisms were not analyzed.

The mean number of organisms per square meter for each of the areas is presented in Table 3-9 (upper horizon) and Table 3-10 (lower horizon). Meiofaunal abundance in each area differed from the patterns shown by the macrofauna. Greatest density was found in area C3, while site ND was second in abundance, followed by areas D2 and D8 (Figure 3-32). Control area C1 showed the lowest meiofauna density.

The analysis of variance failed to show any significant difference ($P>0.05$) in abundance between the disposal and control areas. The mean number of taxa per site showed a very similar pattern, although the differences between areas were not as great (Figure 3-33). Analysis of variance again failed to show any significant ($P>0.05$) differences between the disposal and control areas. The mean meiofauna diversity per site differed slightly, showing highest diversity indices at ND, followed by D8 and D2 (Figure 3-34). No statistical analyses can be presented for diversity values (Green, 1979).

Table 3-9

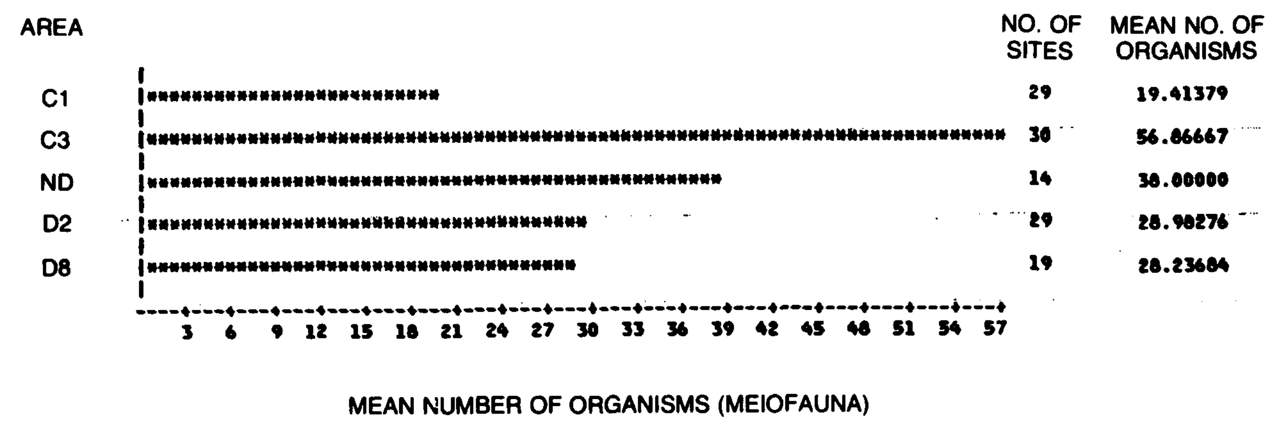
Meiofauna-Upper Strata	AREAS C1	C3	ND	D2	D8	Total Control	Total Disposal
	Organisms/Meter^2 *						
Turbellaria	0	212	122	604	182	212	908
Gastrotricha	0	53	122	0	455	53	577
Rotatoria	2,334	1,910	3,305	439	3,456	4,244	7,200
Nematoda	21,432	101,962	32,687	37,428	40,833	123,394	110,948
Annelida - Oligochaeta	11,671	26,578	20,690	15,476	7,003	38,249	43,169
Polychaeta	0	212	367	0	0	212	367
Hirudinea	212	159	122	165	91	371	378
Cladocera	637	1,273	1,224	988	273	1,910	2,485
Copepoda (Active) Cyclopoida	7,003	23,713	15,180	10,427	21,553	30,716	47,160
Harpacticoida	16,198	17,135	10,528	3,018	5,820	33,333	19,366
Nauplii	1,273	2,865	3,060	1,317	1,182	4,138	5,559
Ostracoda	1,202	3,767	27,668	22,391	6,093	4,969	56,152
Isopoda	0	371	122	110	182	371	414
Insecta (Chironomidae)	283	371	367	0	909	654	1,276
Gastropoda	0	0	0	55	0	0	55
Pelecypoda	71	371	245	0	0	442	245
TOTAL ORGANISMS	62,316	180,952	115,809	92,418	88,032	243,268	296,259

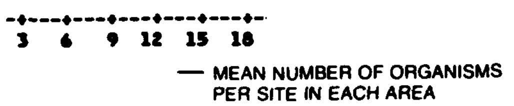
* Based on calculation of organisms/m^2 derived from actual surface sample area of 3.14 cm^2.

Table 3-10

Meiofauna-Lower Strata	C1	C3	ND	D2	D8	Total Control	Total Disposal
	Organisms/Meter^2 *						
Turbellaria	0	0		0	0	0	0
Gastrotricha	0	0		0	0	0	0
Rotatoria	2,387	455		0	12,732	2,842	12,732
Nematoda	0	3,410		6,366	3,183	3,410	9,549
Annelida - Oligochaeta	796	682		0	637	1,478	637
Polychaeta	0	0		0	0	0	0
Hirudinea	0	0		0	0	0	0
Cladocera	796	0		0	0	796	0
Copepoda (Active) Cyclopida	0	3,183		3,183	637	3,183	3,820
Harpacticoida	0	1,364		1,592	3,820	1,364	5,412
Nauplii	0	1,592		0	637	1,592	637
Ostracoda	0	5,229		15,915	637	5,229	16,552
Isopoda	0	0		0	0	0	0
Insecta (Chironomidae)	0	227		0	0	227	0
Gas' opoda	0	0		0	0	0	0
Pelecypoda	0	0		0	0	0	0
TOTAL ORGANISMS	3,979	16,142		27,056	22,283	20,121	49,339

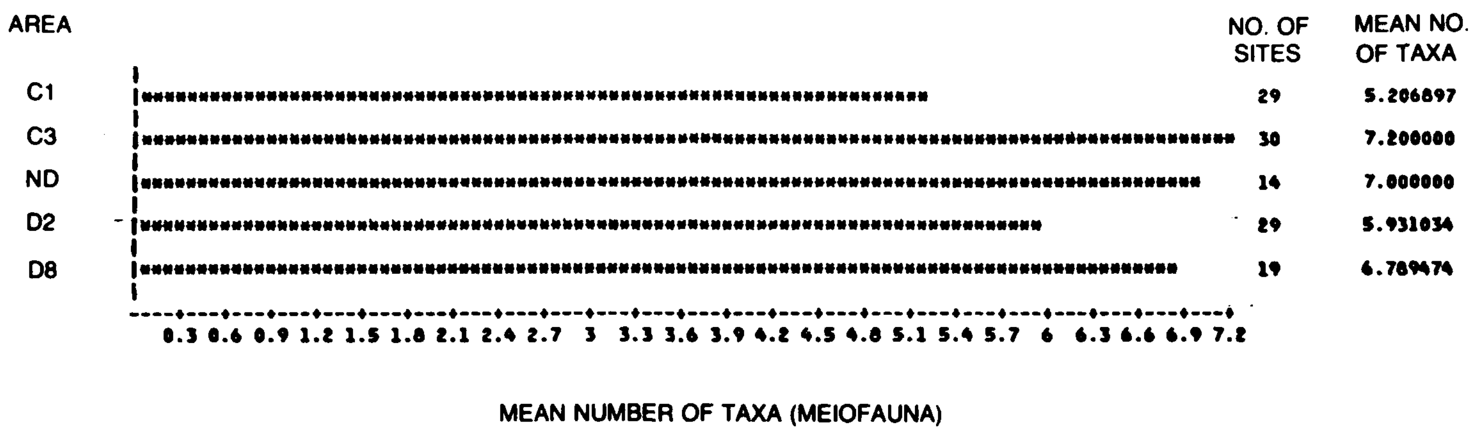
* Based on calculation of organisms/m^2 derived from actual surface sample area of 3.14 cm^2.

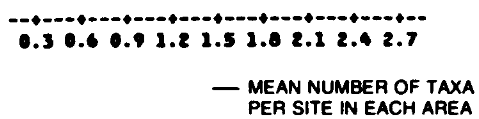




LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

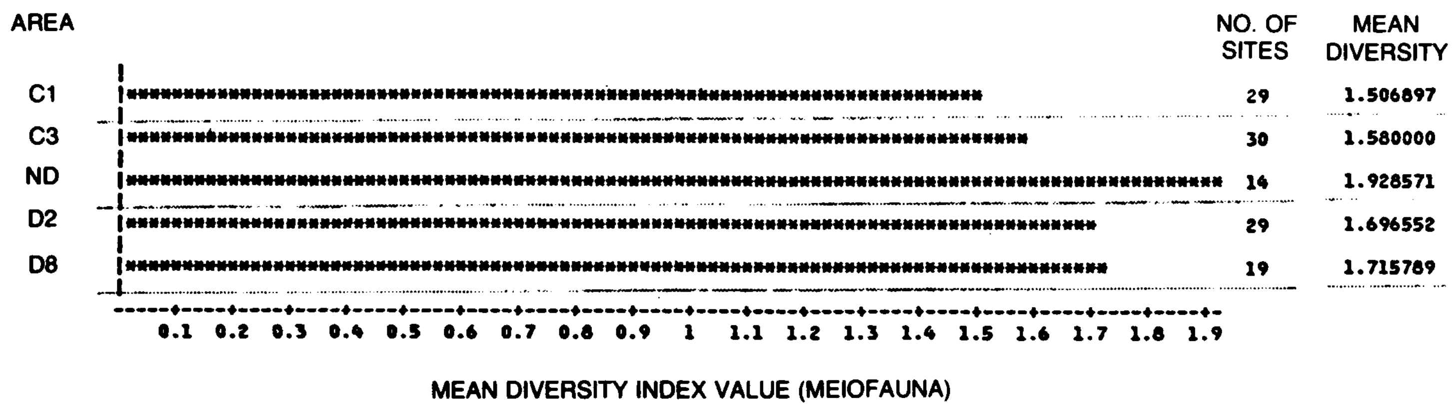
FIGURE 3-32
BAR CHART OF MEAN NUMBER OF MEIOFAUNA PER SITE IN EACH AREA





LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-33
BAR CHART OF MEAN NUMBER OF TAXA (MEIOFAUNA) PER SITE IN EACH AREA



0.1 0.2 0.3 0.4 0.5 0.6

— MEAN DIVERSITY PER SITE IN EACH AREA

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

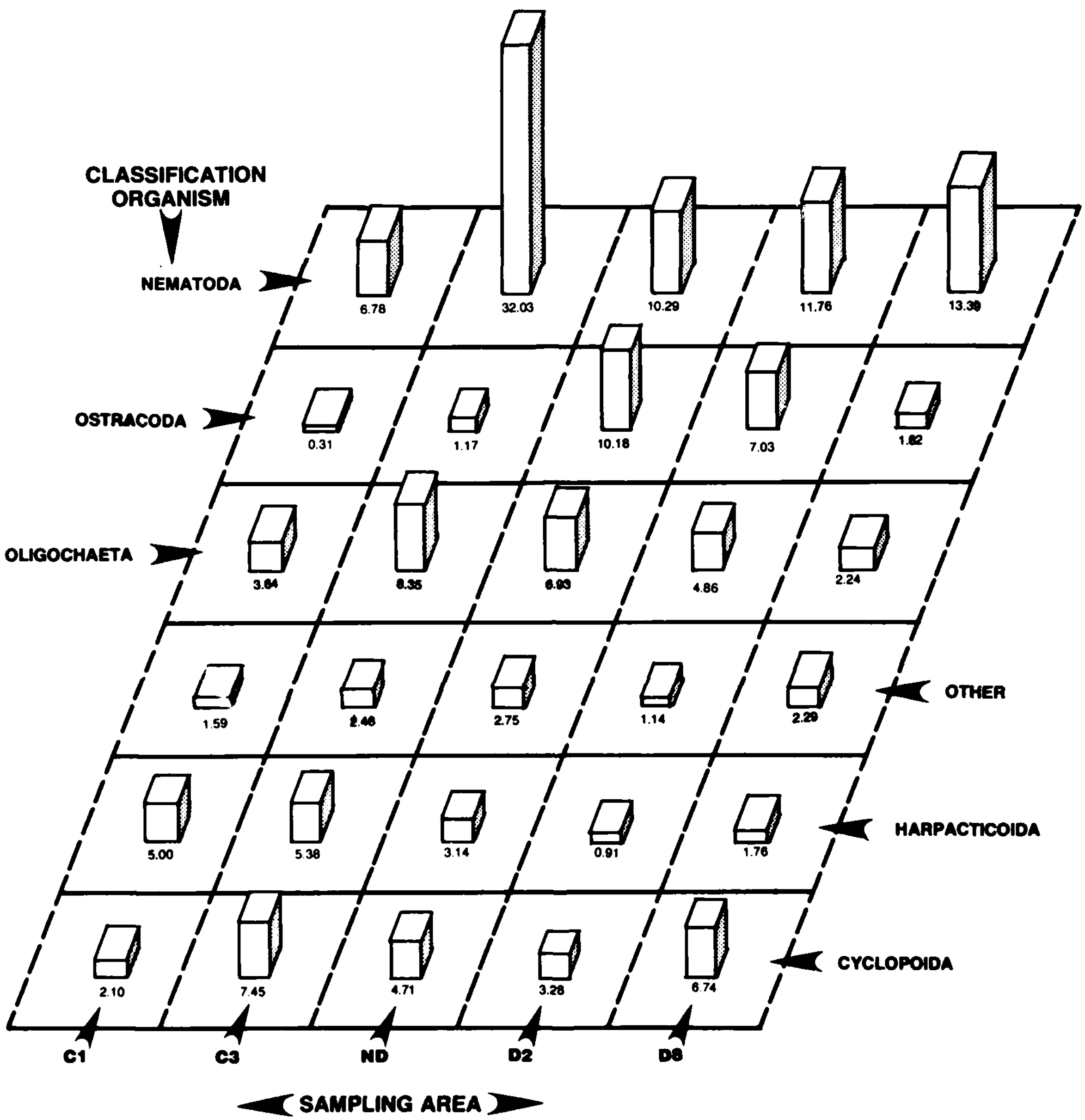
FIGURE 3-34
BAR CHART OF MEAN DIVERSITY (MEIOFAUNA) PER SITE IN EACH AREA

The Nematoda strongly dominated the meiofauna of both control and disposal areas. Harpacticoid and cyclopoid copepods, as well as Oligochaeta accounted for the majority of other organisms in all the areas, with ostracods additionally abundant only in the disposal zones. The Gastropoda were found only in disposal area D2; however, these densities were so low as to make interpretation questionable. All other groups were relatively evenly distributed between the control and disposal areas for the whole data set.

This is demonstrated by a block chart representing the mean number of the major meiofauna taxa per site found in upper horizon samples (Figure 3-35). Mean organism abundance/area was similar between control and disposal zones with the exception of a few individual taxa. Harpacticoid copepods and nematodes were more common in the control areas, while ostracods and cyclopoid copepods were present in greater numbers in the disposal zones.

A block chart of the balanced data set with similar sediment characteristics (Figure 3-36) showed greater faunal variation between disposal and control areas among nematodes, cyclopoids, and, to a lesser extent, harpacticoids. The opposite was true for the ostracods, in which variation decreased with data balanced for similar sediments.

Meiofauna density was markedly reduced in all lower strata samples as compared to the upper horizon (Table 3-10). Disposal area densities, however, were more than two times greater than densities in the control areas. Ostracoda, Rotatoria, Nematoda, and Copepoda dominated the lower strata community, and were considerably more abundant in disposal areas. Oligochaetes and copepod nauplii were slightly more



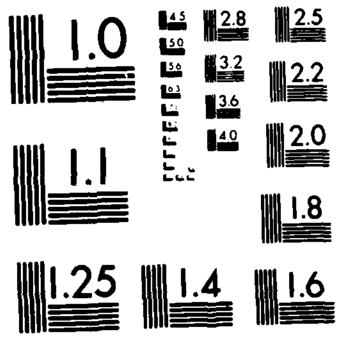
5.00 — MEAN NUMBER OF ORGANISMS PER SITE (REPRESENTED BY A CYLINDER CORE SAMPLE OF 3.14 CM²)

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

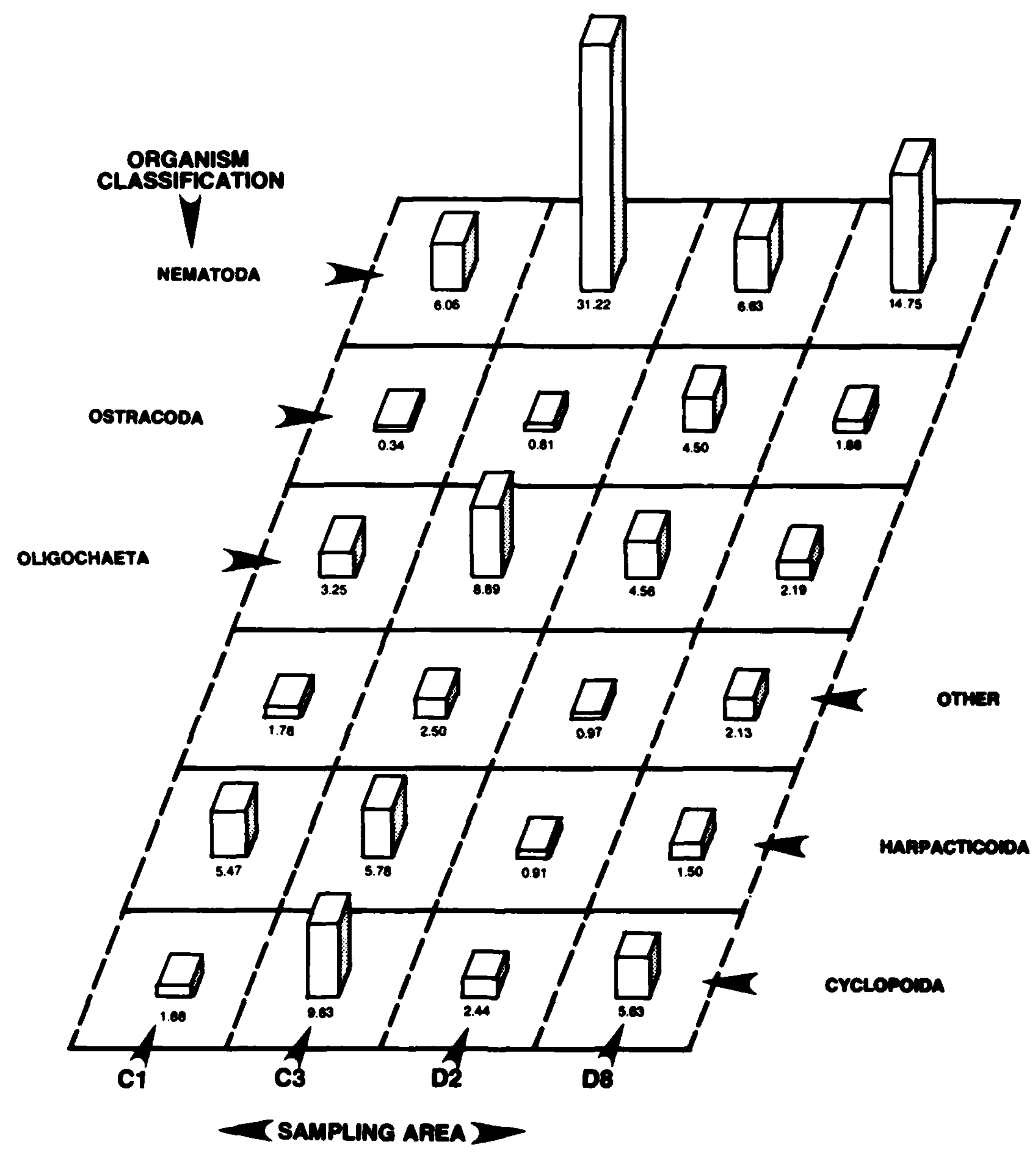
FIGURE 3-35
BLOCK DIAGRAM OF MEIOFAUNAL GROUPS – WHOLE DATA SET

AD-A146 720 LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA OHIO(U) WESTON (ROY F) INC WEST CHESTER PA K J SALAMON SEP 84 WES/TR/D-84-3 2/2

UNCLASSIFIED DACW39-79-C-0060 F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



5.00 — MEAN NUMBER OF ORGANISMS PER SITE (REPRESENTED BY A CYLINDER CORE SAMPLE OF 3.14 CM²) SUBSETTED FOR SIMILAR SEDIMENTS

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-36
BLOCK DIAGRAM OF MEIOFAUNAL GROUPS – BALANCED FOR SIMILAR SEDIMENTS

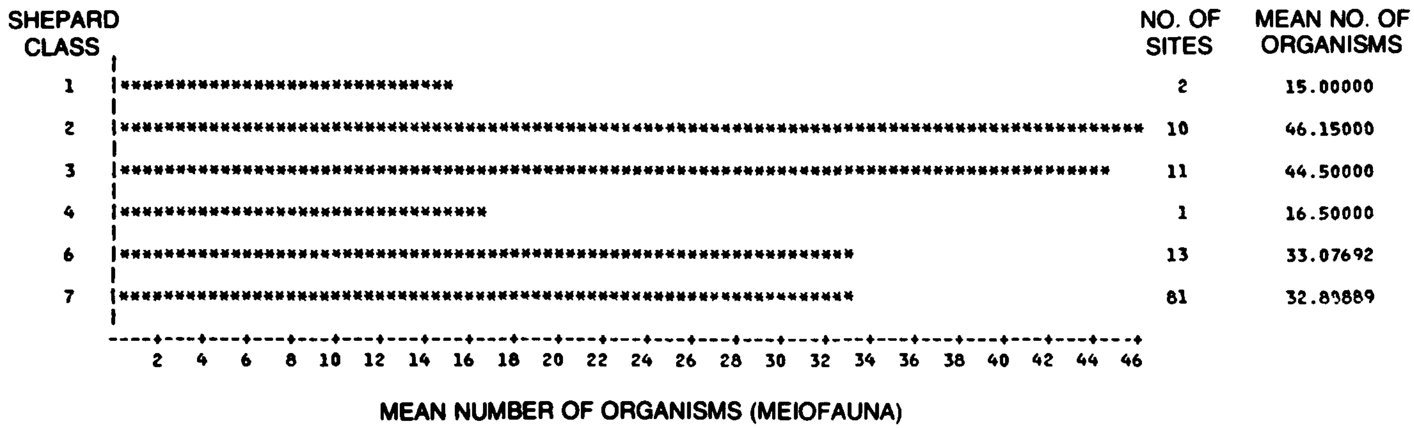
abundant in control areas, while cladocerans and chironomids were found exclusively in the control areas. None of the other meiofauna taxa identified in the upper horizon were found in the lower strata.

3.4.2 Sediment Association

Meiofaunal association with sediments appeared to be bimodal as indicated by a comparison of organism abundance with Shepard Class (Figure 3-37). Highest organism density was found in the coarser grained Shepard Classes 2 and 3, and, to a lesser extent, in the fine-grained Shepard Classes 6 and 7. Relative organism association with the control and disposal area sediments is demonstrated by a bar chart of meiofaunal abundance per station versus Shepard Class (Figure 3-38). Greatest meiofauna abundance was observed in low silt-clay fractions, more common to disposal than control areas.

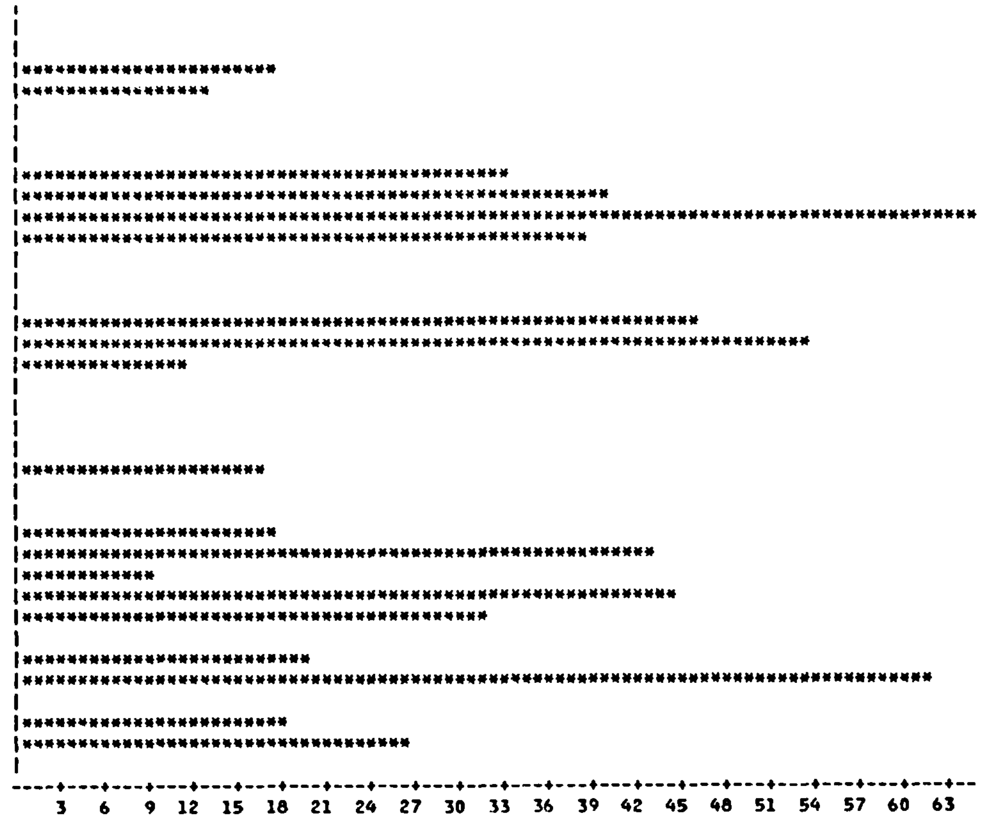
A subsetted data set for similar sediment characteristics was created and examined for the meiofauna. This procedure added little additional information, and is not included in this report. It is postulated that because the meiofauna were represented by a large number of organisms which are generally considered to be epibenthic rather than truly benthic, ties to substrate may not have been as great as the more benthic macrofauna.

Individual taxa density, organized by station and associated with sediment characteristics as a function of Shepard Class, is presented in Appendix E. The majority of organisms present appear to be broadly dispersed among the sediment types.



LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-37
BAR CHART OF MEAN ABUNDANCE OF MEIOFAUNA VERSUS SHEPARD CLASS



SHEPARD CLASS	AREA	NO. OF SITES	MEAN NO. OF ORGANISMS
1	C1	0	0.00000
	C3	0	0.00000
	DN	1	17.50000
	D2	1	12.50000
	D8	0	0.00000
2	C1	0	0.00000
	C3	1	33.00000
	DN	4	39.87500
	D2	3	64.16667
	D8	2	38.25000
3	C1	0	0.00000
	C3	0	0.00000
	DN	7	45.57143
	D2	3	53.16667
	D8	1	11.00000
4	C1	0	0.00000
	C3	0	0.00000
	DN	0	0.00000
	D2	1	16.50000
	D8	0	0.00000
6	C1	1	17.00000
	C3	3	42.50000
	DN	1	9.00000
	D2	2	44.50000
	D8	6	31.25000
7	C1	28	19.50000
	C3	25	61.32000
	DN	0	0.00000
	D2	18	17.97222
	D8	10	26.15000

-+---+---+---+---+---+---+-
3 6 9 12 15 18 21

— MEAN NUMBER OF ORGANISMS IN EACH SITE GROUPED BY SHEPARD CLASS

LONG-TERM IMPACT OF DREDGED MATERIAL DISPOSAL IN LAKE ERIE OFF ASHTABULA, OHIO

FIGURE 3-38
BAR CHART OF MEIOFAUNA ABUNDANCE PER SAMPLING AREA VERSUS SHEPARD CLASS

No exclusive association with a particular grain fraction or area was demonstrated by any of the meiofauna taxa. Association was exhibited, however, by the majority occurrence of certain taxa relative to specific sediment types, regardless of station location. Pelecypoda, Ostracods, Turbellaria, and Polychaeta showed a distinct association with SC-2 and/or SC-3. A slight orientation toward the lower Shepard Classes was demonstrated by the Rotatoria, Cladocera, Cyclopoida, and copepod nauplii, and to the higher Shepard Classes by the Isopoda and Gastrotricha. No obvious preference for any class of sediments was demonstrated by other meiofauna identified.

Differences in mean diversity were observed between control and disposal areas, as well as within disposal areas (Table 3-11). The mean diversity of disposal area ND was markedly greater than all other sampling areas. In addition, diversity indices for areas D2 and D8 were greater than those determined for areas C1 and C3. The range of diversity indices was more narrow in disposal areas, indicating a more uniform population structure. The number of meiofauna lower horizon samples was insufficient for diversity or other analysis.

Particularly noteworthy is the comparability of data for mollusc occurrence and abundance between the study areas, within both the macrofaunal and meiofaunal groups. Pelecypods were found in greater abundance in the control areas among both the macrofauna and meiofauna, while gastropods were present in greater numbers in the disposal areas in both groups. Although sample numbers were sometimes low, the similar occurrence among both groups appears to support the premise of area-specific association for these taxa.

Table 3-11

Meiofauna Taxa Diversity (H)

(mean ± 1 standard error)

Upper Horizon*

	C1	C3	ND	D2	D8
mean ($\bar{x}$)	1.51 ± .07	1.57 ± .06	1.93 ± .06	1.69 ± .05	1.72 ± .06
(n)	29	30	14	29	19
range	0.53 - 2.10	0.71 - 2.06	1.37 - 2.26	1.02 - 2.10	1.02 - 2.06

*Note: Insufficient lower horizon samples for data analysis.

3.5 HEAVY METALS ANALYSIS

3.5.1 Sediment

The concentration of mercury (Hg) and cadmium (Cd) in the sediment of control and disposal areas is presented in Table 3-12. Raw data for these parameters is provided in Appendix F. No significant difference ($P>0.05$) was found between the two study areas for either parameter. In addition, levels of Hg (0.31 - 1.59 μg/g) are well within the range determined in the earlier DMRP study (Wyeth and Sweeney, 1978). No similar sediment Cd analysis was presented by DMRP for comparison with values obtained in the present study.

3.5.2 Interstitial Water

The results of Hg and Cd analyses of interstitial water are presented in Table 3-12. Cd levels were near the detection limit (0.5 μg/l) for all study areas. Hg concentrations were below 2.0 μg/l in all stations sampled. Results for both parameters were comparable to those obtained in the DMRP study (Wyeth and Sweeney, 1978).

3.5.3 Benthic Organisms

Inclement weather on the last day of sampling curtailed the sampling effort for benthic organisms to be used in heavy metals analysis. As a result, the biomass of oligochaetes obtained was inadequate for both Hg and Cd analyses. Consequently, only Cd concentration is presented for oligochaetes.

Table 3-12

Heavy Metals Analysis

Sediment Heavy Metals

Metals		Areas	
		Control	Disposal
Hg(μg/g)	$\bar{x}$	0.94 $\pm$ .08	0.74 $\pm$ .01
	(n)	20	9
Cd(μg/g)	$\bar{x}$	4.85 $\pm$ 0.36	5.30 $\pm$ .58
	(n)	20	9

Interstitial Water Heavy Metals

Metals		Areas	
		Control	Disposal
Hg(ng/ml)	$\bar{x}$	< 2.0	< 2.0
	(n)	23	9
Cd(ng/ml)	$\bar{x}$	< 1.0	< 1.0
	(n)	23	9

Organism Heavy Metals

	Oligochaetes		Molluscs	
Metals	Control	Disposal	Control	Disposal
Hg(ng/mg dry wt)	a	a	0.89	.46
Cd(ng/mg dry wt)	12.5	1.09	.75	.25

a - Insufficient Samples

Results are expressed as the mean ($\bar{x}$) $\pm$ 1 standard error (S.E.); n = number of samples.

All heavy metals analyses were conducted as replicate analyses of composite samples of oligochetes and of molluscs. All organisms were held in clean, fresh water for a period of 24 hours prior to preservation and subsequent chemical analysis. Cd and Hg tissue burdens for molluscs, and Cd residues in oligochaetes are presented in Table 3-12. Concentrations of both Cd and Hg in each animal group were greater in the control than in the disposal areas. However, due to small sample mass, lack of statistically significant number of samples, and possibility of contamination in the oligochaete Cd analysis, little interpretive value can be ascribed to this data.

Since organisms within the respective taxa were composited to obtain a meaningful biomass, numbers are not available for statistical comparison. Comparison of organism heavy metal results with the previous study is also not possible since neither animal metals (DMRP: oligochaete Hg only) nor units (DMRP: wet-weight basis only) are compatible.

3.6 WATER QUALITY

Observed water quality parameters are presented in Table 3-13. Water temperature was generally uniform with depth; vertical gradients varied by no more than 2.5°C throughout the study area. The absence of more pronounced stratification most likely resulted from mixing by storms and heavy seas during the collection period.

Mixing by heavy seas was also evident in dissolved oxygen values. DO remained above saturation at all depths, and ranged from 9.8 to 11.8 mg/l throughout the study period.

pH measurements were uniform within the water column, with values ranging from 8.3 to 8.8.

Table 3-13

Water Quality

Area	Date	Depth	Temperature	pH	Specific Conductance	Dissolved Oxygen	Saturation
		(M)	(^{o}C)		(Micromhos)	(mg/l)	(%)
REFERENCE							
C1	16 August '79	0	21.3	8.6	70	10.4	116
		7	21.4	8.5	70	10.2	113
		15	21.3	8.4	70	10.4	116
C3	16 August '79	0	21.5	8.4	60	10.1	113
		7	21.5	8.4	70	9.8	110
		15	21.5	8.4	60	9.9	111
DISPOSAL							
D2	21 August '79	0	21.4	8.6	190	11.8	132
		7	20.5	8.5	180	11.2	123
		15	19.6	8.5	170	10.6	114
D8	21 August '79	0	21.2	8.5	190	10.8	120
		7	20.8	8.6	180	10.6	118
		15	21.2	8.5	190	10.0	111
ND	21 August '79	0	21.5	8.8	190	11.6	130
		7	21.1	8.6	180	10.9	121
		15	18.9	8.3	180	10.3	110

Specific conductance was uniform within each study area. Values ranged from 60-70 μmhos/cm for control stations, and 170-190 μmhos/cm for disposal areas. The deviation between stations appeared to be a function of changing conditions over time, as opposed to direct association with a particular area.

SECTION 4

DISCUSSION

During recent years, studies have been conducted to determine the effects of open water disposal of dredged material upon benthic communities. The initial impact of dredged material on the benthic community arises from the smothering of existing infauna (McCauley et al., 1977; VanDolah et al., 1979), and results in decreased numbers of organisms and taxa. The number of benthic animals increases over time, by resurfacing of some buried organisms (McCauley et al., 1977), emergence of organisms transported in the dredged material (Sweeney, 1978), and recolonization of the disposal region from nearby areas (McCauley et al., 1977; Sweeney, 1978).

Due to their dependence on the substrate, most infauna are sensitive to any changes in the physical, biological, or chemical characteristics resulting from disposal of dredged material (McCauley et al., 1977). Substrate size, for example, is known to influence the benthic community's infaunal composition (Weiser, 1960). In addition, studies have shown that biomass and/or numbers of some benthic macroinvertebrates are affected by substrate size (Barber and Kervern, 1973).

Changes in the biological character of the substrate brought about by dredge disposal, such as increases or decreases in detritus content, can alter benthic community structure. Barber and Kervern (1973) found strong relationships between macroinvertebrate standing crop distribution and detritus.

In a study conducted in Lake Ontario (Johnson and Matheson, 1968), greater oligochaete biomass was found in those areas where the sediment was rich in organic matter.

Generally, the new sediment surface created by dredged material deposition is available for colonization by the adults of motile species, and by the planktonic larvae of both motile and sessile species. The composition and abundance of species which appear on the material is a function of their motility, and the extent to which they are attracted to, and can survive on, the new substrate (Saila et al., 1972). Wilson (1958) reviewed the factors which mediate settling, including the texture of the surface, grain size, and the presence of substances which induce metamorphosis or have chemo-sensory attraction. The presence of adults of the same species, for example, is frequently a major attractive factor.

In addition, dredged material often contains substances, such as heavy metals, which can alter substrate chemistry and thereby influence community composition. Results of a study by Winner et al. (1980) suggest that the macroinvertebrate community structure exhibits a predictable, graded response to heavy-metal pollution, with particular species appearing in areas of chemical stress.

4.1 SEDIMENT CHARACTERISTICS

Description of the grain size composition and distribution of Ashtabula Harbor - Lake Erie sediments provided a basis for distinguishing dredged material from natural sediments; predicting substrate stability; and elucidating benthic organism-sediment relationships. Dredged material disposal at this open-water site is particularly significant due to the unusually

coarse nature of much of the dredged material. Some habitat alteration was observed in association with disposed coarse-grained fractions. This was noted by comparison to control sediments, as well as by comparative evaluation of the benthic community structure of control areas, in which few distinct spatial variations in grain size were observed. Since shale and gravel disposal apparently occurred after the study by Danek et al. (1977), only limited comparison of this substrate with the earlier study is possible. Nevertheless, sampling at these coarse debris sites provided data on sharply contrasting sites, as well as for evaluation of a more recent disposal event.

Contrasting results have been obtained in many studies made on the repopulation of aquatic sediments after dredge disposal (Pfitzenmeyer, 1975; McCauley et al., 1977; Rosenberg, 1977; VanDolah et al., 1979). The investigators generally found little widespread or long-term effects of dredged material disposal. In each case, the grain-size distribution between the dredged area and disposal sites was not distinctly different, and was distinguishable only by statistically large samples and consideration of distribution ratios. The fact that most dredged material is unconsolidated, low density sediments (i.e. 0.1 - 1.0 mm size range) common to maintenance dredging operations in high sedimentation areas, appears to be responsible for the general lack of distinct sediment differences. Such deposits may be re-entrained into the water column, becoming available for transport by wave drift; indiscriminate settling of these light fractions may mask surficial differences between disposal and control areas.

Differentiation between disposal and control areas by particle-size analysis was augmented during the previous study by distinguishing the high content of plant debris, cinders, coal fragments, and iron pellets in the disposal versus the control areas (Sweeney, 1978). Sweeney (1978) also noted an increase in the

amount of fine sand at the disposal sites after dredged material disposal. Data from the present study, on the other hand, show an increase in coarse sand and gravel fractions as compared to previous disposal area data (Wyeth and Sweeney, 1978). Recent disposal of Ashtabula Harbor jetty material by the Buffalo District Corps of Engineers appears to have been responsible for the change in substrate. In addition, although control area sediments generally tend to be texturally similar to the sediments sampled in those areas during 1975-1976, present analyses do not confirm Sweeney's 1978 finding of a 45 percent sand content. This discrepancy appears to have resulted from a tendency by the earlier researchers to generically describe "borderline" silty-sand as sand, whereas such material was classified as silt using the SEDAN program.

Disposal areas D8 and ND exhibit the most contrasting patterns of sediment distribution. Locations of the various isopleths suggest multiple disposal events and sediment types. High variability is evidence by the random occurrence of up to 94 percent sand and gravel, ranging to typical control area silt-clays. Disposal areas D8 and ND contained 17 percent gravel and shale.

Disposal area D2 was most similar to the typical control area substrates. A pattern of high sand concentration was observed in the northwest sampling zone, decreasing as silt and clay increased toward the southeast. Grain-size distributions in the southeast corner approach those of control areas. This pattern appears to have resulted from coarse dredged material deposition in northwest D2. The finer grained fractions from the discharge were transported to the east according to the prevailing drift during the time of disposal.

Comparison of grain-size distributions with distance from the apparent disposal site suggests that sediment winnowing was the controlling factor. A contour effect to the southeast was created as lighter fractions tended to settle more slowly, resulting in a mechanical sorting of the material.

The silt-clay ratio of all the disposal zone samples falls within a narrow range, very similar to the high silt-clay ratio of the control samples. This suggests a continuous regional substrate with a surficial deposit of coarse-grained material overlying clayey-silt sediments. The presence of lighter fractioned dredged material may have been shrouded by its similarity to the disposal region sediments, or "diluted" by winnowing and drift. Since each sample was analyzed as a composite, the silt-clay fraction may be more representative of the underlying natural substrate, while the sand fraction may represent the majority of disposed dredged material.

The complexity of long-shore currents prevailing in the study area during the time of disposal, as well as the outlet of the Ashtabula River, may have strongly influenced the pattern of sediment distribution. The symmetrical dispersion pattern observed throughout the disposal areas is indicative of a current effect contributing to the scour, resuspension, and sedimentation of discharged materials. Similarly, Sweeney (1978) postulated the occurrence of a complex set of forces affecting the sediments, both during and after disposal operations. The previous study suggested that mixing and induced currents from disposal operations produced textural changes consisting of a surface layer of dredged material, followed by an intermediate area of mixed sediments, and the original lake sediments.

Although this conclusion is supported by the present data, no clear-cut differentiation may be made relative to the earlier study since sand, in concentrations as high as 50 percent (Wyeth and Sweeney, 1978), was present throughout predisposal samples. The apparent reduced occurrence of sand in control areas during the present study may be the result of random sampling, compounded, as noted above, by different definitions of "sand".

4.2 MACROINVERTEBRATES

The various mechanisms of reestablishing a benthic community in substrates altered by dredged material deposition appear to have been in operation at the Lake Erie, Ashtabula, disposal site. Data collected in the present study showed that the disposal areas supported a community which differed little from the predisposal community (Sweeney, 1978) or from the control areas' community. Although abundance and number of taxa were reduced in the disposal areas, they were not found to differ significantly from the control areas.

The Ashtabula benthic macroinvertebrate community seems to be similar to that occurring in the central basin of Lake Erie described by Cook and Johnson (1974). Cook and Johnson described this community as being dominated by the Oligochaeta, Chironomidae, and Sphaeriidae, and having a density of approximately $2400/m^2$. This corresponds closely with findings of this study, with the exception that the isopods, not noted by Cook and Johnson, were found in sizable numbers in the present study.

Similar patterns emerged in taxa occurrence between earlier Ashtabula investigations (Sweeney, 1978) and the present study. In both the DMRP and the present study, oligochaete abundance

was very high, with no area showing less than 49 percent composition. In addition, the dominant adult species Aulodrilus pluriseta and Limnodrilus hoffmeisteri retained their dominance between the two studies.

Five macrofaunal groups were identified in the previous study as being responsible for discriminating between control and disposal areas: Gastropoda, Chironomidae, Oligochaeta, Sphaeriidae, and Isopoda. In this study only the Gastropoda and Sphaeriidae were found to differ significantly between the control areas and the disposal areas.

The fact that the Pelecypoda (Sphaeriidae) were found in considerably higher densities in the control areas than in the disposal areas may not reflect the effects of the disposed dredged material. In the predisposal studies, Sweeney (1978) noted that the Sphaeriidae were found in much higher numbers in the reference (control) areas than in the proposed disposal areas. Thus, the interpretation of the differences noted in this study is very difficult, and no definitive conclusions can be drawn. Furthermore, the higher numbers of gastropods in the disposal areas in relation to the control areas in this study were also noted in the predisposal studies in July of 1975 (Sweeney, 1978).

Although the sediment material from D2 and D8 still showed differences from being dredged from two different sources (river dredgings at D8 and harbor dredgings at D2; Sweeney, 1978), faunal differences noted by Sweeney are no longer present. Whereas Sweeney reported the disappearance of isopods and chironomids, as well as the dominant succession by Aulodrilus sp. in D8 and Limnodrilus sp. in D2 (as a result of differences in dredged material sources), few significant differences remain

in the present study, each area having been recolonized to a more or less equal state. D2 continues to support a more abundant benthic community (as noted by Sweeney) but this may be the result of greater and more suitable surface area for colonization since D2 had considerably less gravel than D8. In contrast to the short-term situation observed by Sweeney (1978), the two disposal site communities did not continue to respond in "completely different ways following disposal" (with respect to recovery of these communities), despite the fact that sediment differences were still obvious. This is unusual in that sediment types strongly influence the abundance and diversity of benthic communities (Odum, 1971), and faunal variability and heterogeneity are, in general, directly related to substrate.

The largest benthic populations were observed in association with sediments with high Shepard Class values,i.e. high silt-clay fractions. This was somewhat unexpected since the lower Shepard Class sediments would seem to offer a greater variety of habitats, ranging from clay to gravel, and would seem capable of supporting a greater diversity and abundance of organisms. However,the profundal nature of this inshore habitat has, in an adaptive sense, shown selectivity for organisms capable of surviving the more characteristic soft substrates typical of this habitat. Thus,the more diverse substrates may not really present an opportunity for increased colonization , abundance, and diversity.

Particularly noteworthy in the present study is the fact that by elimination of some of the sediment-specific differences (considering only a data set having high silt-clay percentages and sediment characteristics), it was shown that the disposal

and control areas contained similar species. These analyses suggest that few inherent differences exist in organism abundance, or number of taxa, between disposal and control areas. The lack of differences between the two areas suggests that the effects of the disposal, other than direct physical habitat modification, are minimal and that the effects of potential contaminants, if any, leaching from the dredged material also appear to be minimal.

Statistical significance could not be demonstrated for major taxon specific association with sediment type, even though most organisms appeared adapted for silty bottoms. Although several organisms were found exclusively in specific Shepard Classes, high variation in organism density between individual stations within sites, and similarily of fauna across sites obscured specific associations. Failure to show organism-sediment relationships using Pearson's Moment Correlation appears due to the bimodal nature of those associations.

Transplantation of adult benthic invertebrates from the dredge source areas may have occurred, although the establishment of new, permanent populations offshore seems unlikely. The planktonic larvae of many of these same species would have previously colonized the area if the habitat had been suitable. Nevertheless, a strong case may be made for Peloscolex which was found predominantly in Shepard Class 3 (common to the dredged material), and in greater abundance in the disposal than control areas.

Organism densities and diversities were much higher in the upper 10 cm of substrate than in the lower 10 cm. Low oxygen concentrations, reduced interstitial water content, increased compaction, and highly reducing conditions in deeper sediments

(Oliver and Slattery, 1976) generally limit population growth. Organism abundance in the upper horizon was as much as ten times greater than that in lower strata. The relative success of the lower horizon population, however, does reflect the ability of these organisms to tolerate adverse environmental conditions.

4.3 MEIOFAUNA

The distribution and dynamics of aquatic benthic communities are dependent on the mechanical composition of the substrate. Graded faunal assemblages generally result as a function of three ecological groups: 1) taxa with affinity to sand (low Shepard Class); 2) taxa with affinity to fine deposits (high Shepard Class); and 3) more eurytopic species (Wieser, 1960). Thus the sediment composition requirements of the meiofauna, a term coined by Mare (1942) to characterize metazoans of medium size, may be somewhat different than those of the macrofauna.

The meiofauna of the Ashtabula Harbor - Lake Erie dredge disposal area show distinctly different patterns of occurrence than the macrofauna. Although the predominance of a bimodal habitat preference among meiofauna characterizes these organisms as eurytopic, high abundance in the disposal area suggests an association with the coarser grain sizes. Qualitative support for this premise is given by the fact that control site C3, in which low Shepard Class sediments are plentiful, showed the greatest meiofaunal abundance (sharing this majority with the predominant high Shepard Class sediments). Site C1, on the other hand, had little or no low Shepard Class sediments, and consequently yielded the smallest number of organisms.

Indices of diversity were also greater in all disposal areas as compared to the control sites. The more narrow range of diversity values indicates a more homogeneous environment. The absence of somewhat higher diversity values may be the result of factors explained in Section 4.2.

Vertically, the meiofauna were more concentrated in the upper 10 cm, as noted for macrofauna. However, in contrast to the macrofauna, meiofauna abundance in the lower strata was greater in the disposal than in the control areas. Nevertheless, no significant organism-sediment relationships were demonstrated, due most likely to the large variability between sites. The occurrence of organisms broadly dispersed among sediments, and showing bimodal substrate preferences may serve to counter-balance data in discrimination techniques. The elimination of sediment-specific differences in the data analysis seemed to support this statement. Variations in organism abundance between test and control areas increased or remained the same for all but one taxon when balanced for similar sediments, thus indicating no sediment association. Only the Ostracoda showed less variation in organism abundance when differences related to grain size were eliminated. The data suggest a distinct sediment association for this taxon. This is further supported by the significantly greater abundance of ostracods in the disposal, as compared to the control areas. No similar relationships could be detected for any other meiofauna taxa.

Since meiofauna were broadly defined with regard to taxon, no "new" species, transplanted as a result of dredged material deposition, were identified. In addition, meiofauna taxa identification was not analogous to that of the previous study. Few conclusions are possible, therefore, regarding earlier meiofaunal conditions. One meiofauna taxon, however, the

Nematoda, was identified during the previous study as being a discriminant organism between reference and disposal areas. Comparison to the present study shows nematodes remaining discriminant with regard to greater control area abundance. Possibly significant, however, is the fact that the density of these organisms has increased by a factor of approximately 300. The Nematoda are the numerically dominant organism of the meiofaunal-macrofaunal complex in the Ashtabula dredge disposal area. Their success during the intervening years has been dramatic, strongly outnumbering the Oligochaeta, which were the dominant organisms present during the earlier study.

Also noteworthy in a comparison between the DMRP and present study is the greater abundance of Ostracoda in the disposal as compared to the control area. Their continued success in the disposal zone further supports the DMRP conclusion that ostracods were transported in the dredged material to the lake habitat (presumed also for several of the oligochaetes), possibly becoming more successful than existing species. In addition, Harpacticoida populations were found to be impacted in the earlier study, but appeared to be reestablished within a year after disposal operations had ceased (Sweeney, 1978). Results of this study, however, demonstrate a more long-term effect; harpacticoid abundance remains markedly greater in control than in disposal areas.

The composition of benthic fauna is generally acknowledged to be a good environmental indicator because, unlike planktonic organisms, components form relatively stable communities in the sediments which integrate changes over long time intervals,

and which reflect characteristics of both the sediments and the water column (Cook and Johnson, 1974). The slight community alteration occurring among the meiofauna appears to be moving toward such stability. No disposal effect, other than providing a wider range of substrate habitat, appears to be occurring among the benthic meiofauna.

4.4 HEAVY METALS

No significant difference in heavy metals (Cd,Hg) concentration in sediment or interstitial water was detected between the control and disposal areas. Mercury levels in sediment (0.31-1.59 μg/g) and interstitial water (<2.0 ng/ml) were compatible with those measured in the previous study (Wyeth and Sweeney, 1978), as well as with levels measured in the Cleveland area of Lake Erie (Walters et al., 1974). Cadmium levels in water (<1.0 ng/ml) were also comparable to those observed during the DMRP study. No analogous sediment Cd analyses were presented by DMRP for comparison with values obtained in the present study. However, measured sediment Cd levels ranging from 1.9-6.9 μg/g are considerably higher than the maximum value of 2.4 ppm noted by Walters et al. (1974) for upper sediment layers from Lake Erie. Since high sediment Cd levels were measured in both control and disposal areas, it appears likely that the contamination is a result of localized industrial discharges as opposed to dredged material disposal. The lack of any cadmium or mercury "hot-spots" in the disposal area appears to negate the possibility of metals redistribution from this area. Thus cadmium and/or mercury impact from the existing dredge sources is most likely negligible.

Although the finding of greater Hg and Cd concentrations in molluscs, and Cd concentration in oligochaetes (Hg values not

obtained due to lack of adequate biomass) in control than in disposal areas coincides with results presented by Wyeth and Sweeney (1978), biological data in this study is inadequate for meaningful interpretation. The low sample biomass, and resultant single measurement per species and category makes significant evaluation or comparison to the previous investigation impossible.

4.5 LONG-TERM IMPACT TO THE BENTHIC COMMUNITY

Analysis of habitat alteration and biological impact assessment were dependent on two major factors not directly comparable to the previous data base: 1) The presence of large tracts of shale and stone in the disposal areas, particularly ND and D8; and 2) single period sampling, providing, in effect, one data set.

Consideration of the former is integral to an understanding of organism:substrate association. Most profundal benthos, for example, are deposit-feeders (e.g. oligochaetes, nematodes) adapted to a burrowing life in soft sediments, and deriving nutrition primarily from bacteria by continuously ingesting large volumes of sediment.

Single period sampling, on the other hand, limits the spectrum of species presence to a single point in time. Population abundance relationships, with the possible exception of oligochaetes, may show considerable seasonal variation, changing particularly as a function of tolerance to adverse conditions. Thus species abundance and evenness, in this case, are more suitable as descriptive parameters to demonstrate intra- rather than inter-study comparisons. Nevertheless, since benthic communities are not subject to as wide-ranging natural population fluxes as plankton, elucidation of critical or long-term impact may be possible between investigation periods.

Results of grain-size analysis indicate that disposal zone sediments are no longer in predisposal condition, as reported by Wyeth and Sweeney (1978). The deposit of jetty rubble has apparently caused a long-term alteration of much of the disposal area. Nevertheless, the present study results indicate little alteration in community structure and stability from predisposal conditions (Sweeney, 1978). Little of the observed population imbalance may be statistically differentiated from naturally occurring patchiness. Where observed, variation between the study areas is most likely associated with the substrate, becoming more obvious as deposited sediments gradate toward very coarse fractions, and appearing as a contrast between reference and disposal sites.

Investigators have demonstrated similar results in other open water disposal studies, generally qualifying the impact on benthic communities as temporary. VanDolah et al. (1979) studied the response of a South Carolina Bay macroinvertebrate community to the unconfined disposal of dredged material. The authors found a reduction in animal numbers immediately following disposal, with recovery occurring within one year. Community structure was altered and species diversity decreased following disposal; organism biomass and numerical abundance, however, remained unchanged. After six months, community complexity returned to is predisposal level, but was composed of a different species mix.

In another study (McCauley et al., 1977), the acute effects of dredged material disposal on the infauna of Coos Bay, Oregon, showed a similar pattern. Initial response showed a decrease in benthic infauna abundance. The dredged material created a fairly uniform layer which destroyed the natural patchiness of the infauna and produced a temporary increase in diversity and evenness values. After two weeks, abundance, diversity, and evenness numbers returned to predisposal levels.

Although the disposal area sediments are not in predisposal condition, and may be representative of dredged material from different sources, few faunal differences appear to exist. Results of this study indicate little long-term alteration in community structure and abundance. Control versus disposal site discrimination by taxa, since the previous study, has been greatly reduced. Likewise, heavy metals impact to the sediment, interstitial water, and benthic community is negligible.

Several differences in organism abundance between the control and disposal areas were demonstrated among several key taxa. Since few statistically significant differences were detected, those observed may have resulted from one, or a combination of, contributing factors: 1) true site comparability may have been masked by single season sampling, resulting in "snapshot" variation due to natural seasonal succession; 2) benthic communities tend to exhibit natural community patchiness; 3) site-specific distribution and composition may simply have been a substrate effect, demonstrating the organism's optimum or preferential location; or 4) variation in relative abundance and composition was, in fact, the direct effect of dredged material disposal. Since no dramatic or critical differences or impact could be shown, the ecological significance of dredged material disposal at the Lake Erie, Ashtabula Harbor, location appears to be minimal. In addition, the disposal areas are comprised of a benthic macroinvertebrate community which shows little difference from the predisposal community, further supporting the assumption of minimal long-term impact.

SECTION 5

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